My Lifelong Road to Light

Outstanding Soviet Scientists

L.V. LEVSHIN

MIR PUBLISHERS MOSCOW

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This book is about Sergei Ivanovich Vavilov, one of the most eminent physicists of this century. Sergei Vavilov contributed so greatly to the development and organization of science that he is considered one of the founders of Soviet physics. His remarkable achievements in physical optics earned him the USSR State Prize on four separate occasions. He was President of the USSR Academy of Sciences for many years.
The book is written by Professor Leonid Vadimovich Levshin, a great authority on luminescence. Indeed his interest in this topic was inspired by Sergei Vavilov himself.

Л. В. Левшин

Свет — мое призвание

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TO THE READER

Mir Publishers would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make.

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> If what you have chosen is the path of
> a scientist you should never forget
> that you have devoted yourself to the
> unceasing quest for all that is new,
> and a life that knows no peace until
> its very end. Every scientist should be
> endowed with the omnipotent gene of
> restlessness that manifests itself in
> no other form but obsession.
>
> *N. Vavilov*

Whenever we speak of the history of physical studies in this country what comes most readily to mind is the multitude of those scientists who have enriched physics with their own labour. However, only few of them have been able to become the founders of entirely new domains in science. This fact can hardly be accounted for by either the lack of any tangible achievements, or the unoriginality of his research. What proves to be of vital importance is the creation of a scientific school and the ability to most effectively direct the efforts of those involved in the research itself.

Sergei Ivanovich Vavilov belonged precisely to those whom we consider to be the founders of science, and he is, by right, regarded as one of the founders of Soviet physics. He left us when he was still at the peak of his powers. Many of his ideas remained unrealized, though the significance of what he had accomplished made his name indelible in the annals of his own country and elsewhere.

It was most fortunate for anyone to meet a man like Vavilov, and my own fate was most kind to me in this respect. My father Professor Vadim Leonidovich Levshin worked with Sergei Ivanovich Vavilov for almost thirty years and was one of his friends.

One day, in May 1927, my father came to the laboratory with the joyful announcement that I was born. Sergei Ivanovich congratulated my father on the happy event and opened his bag to take out a newly published book. It was his own translation from the Latin of Isaac Newton's classical work *Optics*. The dedication on the flyleaf read: 'To dear Vadim Leonidovich for the edification of his son. From S. Vavilov.' This was how my first

acquaintance with Sergei Ivanovich, though not in person, was made many years ago.

When I was twenty and when I had decided to become a physicist myself, I received that book as a present from my father who wrote his own dedication to me on one of its pages. Vavilov's remarkable work is being cherished in our family as one of its most precious heirlooms.

In those years our family lived in two small rooms in a communal flat of an old mansion in Bolshaya Yakimanka (now Dimitrov Street). The house was known to have survived even the Moscow conflagration of 1812. It was here that Sergei Ivanovich would come in the evenings. On cold wintry days he liked to warm his numbed fingers on the tiles of our big Dutch stove.

The first time I saw him at our home, as far as I can remember, dates back to 1932 when Vavilov was already living in Leningrad where he headed the State Optics Institute. It was the time when he paid no more than flying visits to Moscow. What comes back to my mind is that there appeared in our house a large man, joyful and kind, who took me up into his arms, patted me on the head, and said something that must have been very nice.

I also remember meeting him at a much later date. The scene that stands vividly before my eyes is how Vavilov and my father were sitting at the table, their loud voices accompanied by gestures and their discussion interspersed with short breaks during which they were hastily making notes. Some time later, in answer to my questions, my father used to tell me that in trying to find the right interpretation of the results of the experiments that they carried out together they would often be engaged in heated arguments.

I happened to follow Vavilov's career at different periods of his life and under various circumstances. It was not infrequent that I met and spoke with him and watched him talk to other people. At home I was accustomed to hear his name mentioned practically all the time and came to know quite a lot about this remarkable man from my father and his immediate colleagues.

In 1949, when I was a fourth year student at the Physics Faculty of Moscow State University, I was assigned to do my diploma paper at the luminescence laboratory of the Lebedev Physical Institute of the USSR Academy of

Sciences. Vavilov was at the head of that laboratory and it was he himself who recommended to me the subject of my research.

The investigations that I was conducting were part and parcel of what lay within the scope of Vavilov's own scientific work, for which reason he took a lively interest in what I did, thus making it possible for me to see and talk to him on many an occasion. These meetings with Sergei Ivanovich within the last one-and-a-half years of his life have remained indelible in my heart, and I shall remember him with gratitude for the rest of my life.

Under the influence of my father, Vavilov and his pupil Mikhail Galanin, who was my immediate scientific adviser, I began studying the phenomena of luminescence and have forever bound my fate with this fascinating branch of physical optics. In my scientific pursuits I was invariably encouraged by the example set by Sergei Vavilov, who not only conducted fundamental research on the nature of optical phenomena, but was also most seriously concerned with the problems pertaining to the history of the science of physics.

I often think of Sergei Ivanovich, and can easily picture him standing before me — the man whose appearance was unforgettable. His wife Olga Mikhailovna presented a vivid portrait of him in her reminiscences:

'Sergei Ivanovich was of medium hight, not broad in the shoulders, but upright, which imparted to his figure a look of astringent agility. He held himself straight, walked fast, and was light-footed. The perfect shape of his head concealed its size. His dark, thread-like and very soft hair was parted in the middle, and when it moved up it seemed to reveal his high forehead. He had a large and characteristic mouth, a short nose that was well in conformity with the other features of his face, and wonderful Russian dark eyes that spoke of the unfathomable wisdom and kindness rather than possessed any trace of "oriental softness" and languor. When he saw that they arrested the attention of someone he was talking to he either looked aside or hid them under the cover of his dark eyelashes. He had a swarthy complexion and became heavily tanned in summer. His voice was low and of very soft timbre. The expression of his face was strict, profoundly serious and concentrated, though there was

nothing easier than to make him smile. He could laugh till he cried, and could always appreciate or concoct himself a joke or a witty remark.

He was brought up in a well-to-do family, in a house where food supplies never seemed to be running out, and where red-letter dates and family festivities were most rigidly observed. But after the four years at the front during World War I and the Revolution, and having experienced all the hardships of that period—cold and a practically famished existence—he had adopted an extraordinarily unperturbed attitude to all the privations and remained indifferent to 'material welfare' for the rest of his life and even when the wolf was no longer at his door.

As far as his sartorial tastes were concerned he adhered to the infallible principle of being neat and proper rather than conspicuous. I remember the day he came back from Italy. He was wearing a blue suit that could do ample justice to the then latest fashion. Sergei Ivanovich looked particularly elegant in it, but to my horror their once family's tailor was immediately summoned who did his best to make the suit unwearable. In answer to all my pleadings Sergei Ivanovich mercilessly replied: 'You really think I am a musical-comedy star?.' That was the end of it.

It is hard not to agree with Albert Einstein, who once said that he was interested not only in the key experimental and theoretical research, but also in the people engaged in this kind of work, their fate, tastes and habits. It is not surprising then that the life and creative activity of Sergei Ivanovich Vavilov has long drawn the attention of those studying the history of Soviet physics. The bibliography about Vavilov comprises over four hundred titles. This list, however, is by far not complete. Information on his life and scientific merits is contained in numerous books, textbooks, and monographs.

The 'Vavilov theme' cannot possibly be considered to be exhausted. There will be quite a few researchers studying his enormous theoretical heritage who will derive from it the ideas that have not become obsolete even today.

I shall be gratified if what I tell my readers about this remarkable scientist and extraordinary man will not prove to be beyond me in my endeavour to accomplish the task.

ROOTS

Before we begin our account of the protagonist of this book it is worth dwelling on the family's annals. We can manage to trace them as far back as the end of the eighteenth century when in the village of Ivashkovo of the Volokolamsk district of the Moscow province there lived a serf named Vavila Ivanovich Vavilov.

Vavila died at the age of seventy in the middle of the last century. His two sons, Ilya, the elder, and Ivan, the younger, who were also under bond-service, had large families and lived in a big house that stood in the very centre of the then growing village Ivashkovo (now it is a population area in the Shakhovskaya district of Moscow region with more than twenty-five thousand inhabitants).

The Vavilovs were cart-drivers, did part-time work on the farms outside their own territory, as well as other jobs connected with minor trades. Ilya Vavilovich's family was particularly large. He had a daughter and seven sons among whom was Ivan Ilyich, the father of the future eminent scientists Sergei Ivanovich Vavilov and Nikolai Ivanovich Vavilov.

Ivan had a good ear for music and a resonant voice, which proved to be the decisive factors in establishing the boy's further progress. The assiduity with which he sang in the church choir had won him the acknowledgement of the local priest, who advised the Vavilovs to send their son to Moscow so that he should take up choir-singing. It took the family some time to make their decision before Ivan Vavilov started on his one-hundred-and-thirty-kilometre walk to Moscow together with the fellow travellers, peasants like himself. The time was the middle of the seventies of the nineteenth century.

Ivan Vavilov succeeded in becoming a choirboy at the Church of St. Nicholas in Vagankovo in Presnya—one of those few places to which the children of peasant families were admitted. As was the custom, Ivan adopted the surname of Ilyin, after the Christian name of his father, and it was only in 1886 that he had restored for himself the family name of Vavilov.

The boy proved to be a capable and painstaking pupil. However, he was not destined to become a chorister, since there remained nobody to pay for his tuition. On

the way to St. Petersburg his father had suddenly died. He was buried in Aleksandr Nevsky Monastery.

Ivan had no means to support himself until his relatives found a job for him with the merchant Saprynin. But soon the boy went to work at the shop owned by the Prokhorovs—the proprietors of the largest textile factory in Russia. The Prokhorov's establishment was founded as far back as 1799 and was built on the hills that bore the name of Tryokhgorka (three mountains), which accounted for the appellation that the cotton mill itself and its production had acquired ever since. Its various fabrics were extremely popular not only in Russia but also in many other countries.

When Ivan first stood behind the counter, he had not yet reached even the age of twelve. Though still a child, he exhibited no minor propensity for commercial transactions. Replete with vim and enterprise he undertook the study of the trade in all its subtle details, going even so far as to come up with his own suggestions to improve the business. There were no assignments that he feared to tackle and had invariably accomplished them with success, always keeping his word.

The Prokhorovs liked the boy for his efficiency and did not grudge him rapid promotion. Thus, within several years he was appointed manager of the shop itself.

At their own cotton mill the Prokhorovs organized a drawing workshop where many talented self-taught artists created highly original patterns for the fabrics. Among them was Mikhail Asonovich Postnikov, a versatile worker who was a splendid artist, draughtsman, engraver, wood-carver, and joiner. In spite of a marked age difference, Ivan and he had soon become great friends. The young man had often been a guest at Postnikov's home where they used to spend evenings discussing the business at the mill, the secrets of craftsmanship and, most certainly, the meaning of life itself.

The one who often took part in those talks was Postnikov's daughter Aleksandra Mikhailovna. The young people fell in love with each other and on January 8, 1884, they got married. The wedding ceremony took place at the Church of St. Nicholas in Vagankovo in Moscow.

The Postnikovs were a large family. Besides the two daughters, Aleksandra and Yekaterina, Mikhail Postni-

kov had three sons—Nikolai, Ivan, and Sergei, who studied at the Stroganovsky School of Arts and were all three promising masters of the brush. However, both the father and his sons were addicted to drink. The brothers died of tuberculosis and their parent finally drank himself to death.

By that time Ivan Vavilov already had his own family. He was in charge of a large trade department in the Prokhorov's firm and soon became one of the directors of the Prokhorov Tryokhgornaya textile company. He was made responsible for the distribution of what the cotton mill produced in the East.

At the beginning of the nineties, Ivan Vavilov together with Nikolai Ipatyev and Nikolai Udalov founded their own business enterprise 'Udalov, Ipatyev and Vavilov'. In the Moscow Trading Centre the partners opened the stalls for selling merchandise produced by the Prokhorov cotton mill. At the head of the business stood Vavilov himself. Ipatyev and Udalov took upon themselves the management of the branch establishment in Rostov-on-Don. Presently Vavilov received the title of merchant of the first guild and was elected a member of the Moscow City Council.

Ivan Ilyich was tall and strongly built. He had an impressive beard and smoked cigarettes of the more expensive brands. It so happened that he had not been able to receive any education but he was well-read, held the views of a liberal, and was known to be an equitable person. His attitude to his subordinates was always kind, and he was ready to render material support to those in need.

In his unfinished reminiscences entitled 'The Beginning of an Autobiography', Ivan's son Sergei wrote the following words about his father: 'He was a man of intellect, a thoroughly self-educated person, who had read and written profusely, and was undoubtedly someone whom we refer to as intelligentsia. I think he was an excellent administrator; his business had always been successful, and he had known no fear in lending his support to any new enterprise. He was a public figure of liberal views, who was as genuinely patriotic as religious. My father was loved and respected by all. Under circumstances different from his own, he would have made a perfect engineer or scientist.'

Another entry into the same reads: 'Father came from a village and was of peasant origin, on which he never failed to pride himself and which had remained in his memory forever. His favourite song, which he was wont to sing to his accompaniment on the piano, was: 'The rich man knows no sandman with his coffer full, the fool! And I sing and rejoice as any church-mouse would.' Ivan Ilyich left an indelible imprint on the memory of not only his children, but his grandchildren as well. One of them, Aleksandr Ipatyev, wrote: 'What I remember of my grandfather is that he was a kind of giant who had power over everything.'

Ivan Ilyich did not accept the October Revolution. He looked with misgivings at the power now in the hands of people and remaining heedless to the wishes of his relatives he decided to leave Russia. A. Ipatyev used to recall the day their grandfather came to bid farewell to them. His belongings were put into a horse-driven carriage, and with his coat and hat on and tears running down his cheeks, he gave each of us a hug.

At first Ivan Ilyich went to Odessa, and in 1918, together with V. Vlasov and his wife E. Postnikova, the sister of Vavilov's wife Aleksandra, sailed for Bulgaria. He settled in Varna, a town on the coast of the Black Sea. Life outside his own motherland, however, could not take its natural course; success deserted Ivan Ilyich, and the old man understood that it was impossible to find happiness 'on a foreign strand' with his family far away from him. He started thinking of returning to his homeland.

In 1921 his elder son, Nikolai, went on a scientific mission to the USA and a number of countries in Western Europe. In January 1922 he managed to find his father in Berlin. Measures were immediately taken to get the permission for Ivan Ilyich to come back to Russia. Difficult as the problem was, it was nevertheless facilitated by the fact that during the period of his emigration Ivan Ilyich had participated in no activities directed against the Soviet Power. However, it did take some time before the permission was granted and Nikolai Ivanovich went to Varna to bring his father home.

In 1928 Ivan Ilyich and his son came to Leningrad. The event was extremely sad. There stood before the family an enervated old man whose health was so poor that he

had to be instantly sent to Sverdlovsk Hospital. What gnawed his conscience was that he saw only too well his guilt before his loved ones and implored them not to deprive him of their merciful forgiveness. For two weeks his wife Aleksandra, his two sons Nikolai and Sergei, and his daughter Aleksandra were at his sickbed, nursing him. But his days were numbered. He died of heart failure at the age of sixty-eight. Aleksandra Vavilova buried her husband in the cemetery of the Aleksandr Nevsky Monastery.

Aleksandra Mikhailovna was a little woman with black hair and large expressive eyes. She was modest, taciturn, and was endowed with both wisdom and a sense of humour. She spoke in a low voice that always sounded pleasant. The no more than elementary education which she received in her childhood was no hindrance for her to develop the inborn talents. Nature had bestowed her with good taste. She took drawing lessons, was remarkably good at needlework, and kept her house in perfect order. Her whole life was devoted to the upbringing of her children.

Aleksandra Mikhailovna was unquestionably the mistress of her own house. She was particularly keen on never allowing her husband to do anything about the house and was adamant in her opinion that each had his or her own duties to attend. She was a stay-at-home type of woman and had practically never been out of her home. Ivan Ilyich, however, had permanently been occupied with his business, and took upon himself the trouble of edifying his children only in those cases when the need to do so was urgent.

In later years Sergei Vavilov used to recall: 'Father had always been at some distance away from us. Already as a child I understood too clearly that he was an ardent reader, that he even tried to write his own poetry, he lived an inner and complicated life of which I was aware but little.'

In upbringing her children Aleksandra Vavilova never condescended herself to pampering them. Her sons and daughters enjoyed the independence that knew no stint.

Aleksandra Vavilova was a hard-working woman who never sat idle. No minor effort was called for to keep the house in perfect order. She was the last one to go to bed, and at five in the morning, when the rest of the family

were fast asleep, she was already actively busying herself about her duties.

The children worshipped their mother. Sergei Ivanovich wrote: 'It is not often that one can find the moral qualities shared by my mother... with the primary school as her sole educational background, she had devoted herself entirely to her family. She had no other interests but those that made her live for the benefit of others. I loved my mother most devotedly and can still remember how the thought had once crossed my childish mind that there might come a day when mother would no longer be with us. It seemed to me that the world would come to an end. I have seen but few such women in my life.'

The years of childhood found the following verbal expression: 'Mother covers the whole of the background. She is the guardian-angel without whom nothing is conceivable. Father is somewhere far away and I hardly know him.' At some other time Sergei wrote: 'Mother comes from a working-class family. Till the very end of her life in 1938 she had never cared to become "grande dame". She washed our clothes and scrubbed the floors herself even in the days when our material well-being was at its highest. I really don't know if one could be more humane, kind-hearted, diligent and democratic than my mother was'.

Sergei was Aleksandra's pet child, and the boy had responded to her love with unfailing obedience.

And this is what M. Tupikova, one of those who had worked with Aleksandra Mikhailovna's elder son Nikolai for many years, said of her: 'She was a slender little old woman. A black piece of cloth covered her head. She wore her hair straight, and below the wide-open forehead under the thick eyebrows her big dark eyes shone mirthfully kind and full of life. She had been unceasingly preoccupied with her housework, taking care of everything and everybody. There was a breath of life's wisdom about her. Her attitude to Nikolai's colleagues, friends and acquaintances was always affable, friendly and hospitable. One might as well say that it was the same to people in general... The elder son treated his mother with great gentleness though not refraining from a bantering remark now and then'.

It was with no minor warmth that Sergei Vavilov's fellow-student at the University, a corresponding member

of the USSR Academy of Sciences, Aleksandr Predvoditelev had spoken of his friend's mother. He, as well as many others, had never been able to forget Aleksandra Mikhailovna's big dark eyes. That was why he persisted in saying that she was of gypsy extraction.

Aleksandra Vavilova gave birth to seven children. They were three daughters and four sons. The first-born children Yekaterina and Vassili died soon after they were born. In 1905 her youngest son Ilya died from appendicitis. He was a precocious child of unusual intellectual curiosity. The rest of those who had managed to survive became scientists.

The eldest daughter Aleksandra, Ipatyeva by marriage, was born in 1886. She was her father's favourite child. He lovingly called her Sanyatka (one of the diminutives formed from the name Aleksandra), giving her much of his time and singling her out among the others. The girl showed no small interest in natural sciences, music and medicine. She always willingly helped her father with the checking of the accounts and handling of other business papers. This was indeed something that brought the father and the daughter get closer to each other.

Aleksandra graduated from the Medical Faculty of Moscow University. After she got married to her father's business partner, Nikolai Ipatyev, the newly-weds moved to Rostov-on-Don. However, their family life was not a success. In 1912, her husband left her and their four-year-old daughter, Tatyana, and son Aleksandr who at that time had not even reached the age of one. There was nothing to do but return to Moscow.

Back at home Aleksandra Ipatyeva received the unanimous support of all her relatives. Her brothers Nikolai and Sergei did all they could to help her bring up her children. In his reminiscences her son Aleksandr Nikolayevich wrote many a word of gratitude to the two Vavilov brothers.

There was a particular affinity between him and Sergei Vavilov. However, it was Nikolai Vavilov who played the decisive role in determining the young man's future career. He advised his nephew to take up horticulture at the Moscow college which specialized in this branch of science, and which proved to be the starting point for Aleksandr Ipatyev, the future learned biologist. In later years he headed the Genetics Department at the

Byelorussian University. In 1968 he was elected corresponding member of the Byelorussian Academy of Sciences. He died in 1969 at the age of fifty-eight.

On her return from Rostov Aleksandra Ipatyeva began working as a physician at the Alabinskaya rural hospital in the suburbs of Moscow. Gradually she became profoundly interested in the problems of bacteriology, and her scientific research brought her no small renown. When she was already a doctor of medicine, she organized in Moscow a number of sanitary and microbiological laboratories.

All her life her brothers Nikolai and Sergei were her greatest friends. They nursed her with utmost care when in 1940 she fell seriously ill and underwent treatment at the Botkin Hospital. However... it was impossible to save her life.

The younger sister Lydia was born in 1893. She did very well in her studies and received a gold medal on the completion of her piano training at the Moscow Philharmonic Society. But it was microbiology that the girl had chosen as her profession. Those who knew her predicted that she would make a brilliant career in science. In 1909 when Lydiya was still an undergraduate of the faculty of medicine at the Moscow Higher Courses for Women, she participated with her elder brother Nikolai in the work of the Twelfth Congress of Russian Naturalists and Physicians in Moscow. She married Nikolai Pavlovich Makarov, the future professor and an eminent specialist in the field of economics.

In 1914 a smallpox epidemic broke out in Voronezh. Lydia Makarova and a group of other doctors immediately went there to eradicate the spreading of the disease. Presently there came to Moscow the news that she had fallen victim to this dreadful scourge herself. Her brother Nikolai Ivanovich left for Voronezh instantly and remained at her bedside until the very last moment of her life. Death had carried away the life of not only Lydia Ivanovna herself but also that of her unborn child.

Lydia Makarova was buried at the Vagankovskoye Cemetery in Moscow. Her eternal resting place was close to where her little sister and the two brothers had found theirs some time before. Her death was a grievous blow to the whole family. The woe had remained inconsolable for Aleksandra Vavilova who kept the graves of her

deceased children in perfect order until she herself departed for evermore.

Aleksandra Vavilova died on April 4, 1938, at the age of seventy-four. Her grave lies close to those whom she had cherished in her heart all her life.

'MY BROTHER WHO HAD BEEN WITH ME SO LONG...'

Nikolai Vavilov was born in 1887. He immortalized his name with his most outstanding research in the field of botany, genetics, and plant growing. He is by right considered to be the creator of the scientific foundations of selection, the study pertaining to the world centres as regards the origin of cultivated plants and their geographical distribution. He was one of the first organizers and those who stood at the head of the biological and agricultural sciences in his country. Nikolai's teacher, Academician Dmitri Nikolayevich Pryanishnikov, when speaking of his pupil, said, 'Nikolai Ivanovich is a genius and the only thing that prevents us from acknowledging this fact is that he happens to be our contemporary.'

It was his father's wish to make Nikolai succeed him in his business, and the boy was sent to the Moscow School of Commerce. However, the young man showed a marked propensity for natural sciences and decided once and for all to become a biologist. In the year 1906, on completing his course of studies at school, Nikolai entered the Moscow Agricultural Institute, otherwise known as the Petrovskaya Agricultural Academy (now the Timiryazev Agricultural Academy). Nikolai Vavilov had an amiable character and was a good mixer with the rest of the students who nicknamed him their 'beauteous sun'.

In 1910 Nikolai published his first scientific paper, which was also his graduation thesis and was titled 'Soft-body mollusks (snails) and their hazardous effect on the fields and vegetable gardens of the Moscow region'. It was duly appreciated by the Moscow Polytechnical Museum and awarded the prize named after the famous Russian anthropologist, zoologist, and historian Anatoli Bogdanov. In 1911 Vavilov graduated from the Institute with honours and was granted the opportunity to remain

at the Department of Farming Agriculture with Academician D. Pryanishnikov as his scientific adviser.

In 1913 the young scientist availed himself of the chance to visit a number of leading agricultural laboratories in England, France, and Germany. The outbreak of World War I made him come back to Russia. In 1917, at the age of thirty, Vavilov was elected professor of the Faculty of Agriculture at the University in Saratov.

In 1921 the Soviet government commissioned Nikolai Vavilov to take part in the work of the International Congress of Agricultural Studies held in the USA. There he organized the Soviet bureau responsible for the introduction (distribution) of valuable plants, and it was through this organization that he had received a fairly large number of the kinds of agricultural plants that were most essential for his country.

On his return to Soviet Russia, Nikolai Vavilov became the Head of the Petrograd Department of Applied Botany and Selection, which in 1930 became the All-Union Institute of Plant Physiology. From that time on he was twice its director, and also in charge of the Laboratory of Genetic Studies, which later received the status of the Institute of Genetics of the USSR Academy of Sciences.

In 1923 Nikolai Vavilov was elected corresponding member of the USSR Academy of Sciences and received full membership coming to him six years later. Meanwhile, he had also been honoured to become a full member of the Academy of Sciences of the Ukranian Republic. In 1935 he was elected Academician of the All-Union Lenin Academy of Agricultural Sciences, of which he had been President since 1929, becoming Vice-President along with this new standing. He held this post until 1940. From 1926 to 1935 Nikolai Vavilov was a member of the Central Executive Committee of the USSR, and from 1927 to 1929 he was a member of the All-Union Central Executive Committee. He was also elected Deputy to the Leningrad City Council of People's Deputies.

Nikolai Vavilov was an outstanding biologist with the widest scope of scientific interests. He attained exactly the same success when undertaking the research into such branches of science as morphology, systematics, anatomy, genetics, selection, physiology, immunity,

and the origin, history, and the geographical distribution of cultivated plants.

In each of these branches of agricultural science he made discoveries of immense practical significance. In 1920 he discovered the law of homologous series in the hereditary variability of plants, according to which there appear similar hereditary variations with related species, genera, and even families of plants.

The law discovered by Vavilov is often compared with Mendeleev's periodic law. By a number of morphological features and properties of one species or genus of plants, it makes it possible to prognosticate the existence of corresponding, and earlier unknown, properties in another species or genus of plants. In practice this law helps horticulturists to receive the original forms of plants for further crossbreeding and selection.

In June 1923 Vavilov made a report on his discovery at the Third All-Russia Selection Congress. It was received with an overwhelming approval by all the delegates. The eminent physiologist Vladimir Vladimirovich Zelensky said, 'The Congress has become an historical event. From now on biology will acknowledge its own Mendeleev.' Another participant of the Congress, Nikolai Maximovich Tuliakov, stated, 'With people like Nikolai Vavilov, Russia will never perish.'

In 1926 Vavilov was awarded the Lenin Prize for his research into the field of the hereditary variability of plants and for the discovery of the law of homological series. In 1940 he was honoured with the Grand Gold Medal of the All-Union Agricultural Exhibition for his work on selection and seed growing.

Nikolai Vavilov was also celebrated as an outstanding geographer and traveller. He is mentioned along with Nikolai Przhevalsky, Nikolai Miklukho-Maklai, and Pyotr Semenov-Tyan'-Shansky. Vavilov went on a number of expeditions in sixty countries of Europe, Asia, Africa, and America. In 1931 the All-Union Geographic Society elected him their president. He held this office till 1940.

Vavilov had a perfect command of English, German and French. He could read Spanish, Italian, and Persian without extensively referring to dictionaries. In many countries he required no interpreter to come into contact with the local population.

The remarkable scientist possessed the rare gift of scientific prognostication. Many years of his travel in the four continents had enabled him to discover the centres of the origin of the cultivated plants on Earth and to find the scientific basis for the choice of the vegetable material that would prove to be relevant to scientific purposes.

As a result of the work carried out by the expeditions headed by Vavilov, there appeared a unique collection of seeds of cultivated plants. This gave rise to the breeding of more than one thousand new kinds of agricultural crops that have been widely spread since. Nowadays the collection of the All-Union Institute of Plant Physiology, preserved in its natural form, contains over three hundred thousand specimens of seeds of cultivated plants. Vavilov's entire activity was wholly devoted to the task of preserving, multiplying and improving the plant wealth of the Earth.

Nikolai Vavilov was obsessed with science. He was fond of reiterating the words: 'Life is brief and there is no time to lose.' Once at a banquet a man who sat next to him said, 'When and how do you find the time for your private life?' Vavilov repeated the final words of the question verbatim. Then he said, 'But isn't science my private life itself?'

People found no words to expess his assiduity. He could work twelve, or even eighteen, hours a day, allotting not more than three or four hours to his sleep and yet looking quite fit and happy. Always painstaking, Nikolai Ivanovich demanded exactly the same kind of attitude to work of those who worked with him. His most favourite token of praise was the phrase 'a hard-working man'.

He did not like the idea when any of his subordinates asked him to allow to go on leave. In cases like these he was wont to say, 'How do you mean? We aren't working at a plant, are we? Why don't you go for a walk into the field, or go to any of our branches for a month or so? Won't that be a good rest? Your humble servant has never been on holiday himself. I really couldn't even imagine staying away from my work!'

Vavilov was not in favour of punishing people, 'I think that any kind of coercion in science is absolutely out of the question. Where the people risk their lives, the rela-

tions should be based on quite a different footing.'

The elder brother of the protagonist of our book was modest in the extreme and had unfailingly been averse to any kind of fuss or accolade. When someone addressed him with the words of eulogy, he invariably replied: 'That is no doubt an exaggeration', 'I'm afraid you're overdoing it,' 'Are you sure you are not overstating my merits?', 'Please don't, it's too much publicity!', etc. After his brilliantly made report at the Fifth Congress of Genetic Sciences in Berlin in 1927, when the storm of ovation had died down, he said to his wife, 'Well, it turns out that we are not on the sidelines after all.'

All his life Nikolai Vavilov struggled for the truth in science. He was not afraid of either the critics, or the reconsideration of the principles that he laid down. The scientific truth was above everything else for him. His works received universal acknowledgement and popularity. The academies of sciences in many countries considered it their honour to regard him as one in their own ranks.

In the wake of D. Mendeleev, I. Pavlov, and K. Timiryazev, he was elected honorary member of the London Royal Society. He was also elected honorary member of the academies of sciences in India, Scotland, and Argentina, and corresponding member of the German (Halle) and Czechoslovakian academies, and honorary member of the Amerian Botanical Society, the Linnean Society in Great Britain, the British Gardeners Society, and many others.

The prohibition to remain in his professional capacity and persecution at the time when classical genetics had fallen into disfavour curtailed his life at the age of fifty-five, when his scientific career was flourishing most profusely.

In his reminiscences of Sergei Vavilov, Academician Vladimir Veksler wrote that Sergei Vavilov had always highly appreciated the talent of his elder brother and was particularly distressed in the days of his misfortune. He had never allowed a thought enter his mind that his brother was guilty and believed that the truth would come out at last.

One might as well presume that the words of Tyutchev, the poet whom the two brothers had cherished, not once came back to Sergei Vavilov's mind:

My brother, who had been with me so long,
You too went there to where we'll all be gone,
And now upon the barren hill up there
Alone I stand—with bareness everywhere.

. . . .

. . . .

Great are the losses, and the days run fast,
The breathing life had breathed long its last,
And nothing there remains for me in store,
But to await my doom, and live no more.

The truth did triumph in the end. The name of Nikolai Vavilov came to be the name of one of the great men in the world history of science. He brought enormous credit to his own country. His heritage comprises over three hundred and fifty scientific articles and monographs, many of which are now by right considered classic. Already for several decades the cover of the international journal of genetic studies *Heredity* includes the name of Nikolai Vavilov next to the names of such luminaries of biology as Charles Darwin, Carl von Linné, Gregor Mendel, and Thomas Hunt Morgan. A special commission of the United Nations Organization has acknowledged the necessity of including Vavilov's theory concerning the centres of the origin of cultivated plants when planning the respective international expeditions.

In 1967 the All-Union Institute of Plant Physiology was named after Nikolai Vavilov. The All-Union Society of Geneticists and Plant-Breeders is also named after him. The most prominent works in the field of genetics, selection, and plant-growing are awarded the N. Vavilov prizes and a special medal in his memory is also awarded by the All-Union Lenin Academy of Agricultural Sciences. Monuments have been erected to him in Saratov and Tiraspol. One of the mountains in the Antarctica also has his name, as do streets in several cities of the USSR.

The Vavilovs were a remarkable family indeed! One could hardly find a better form of expressing one's attitude to them than what was once said by Academician Vladimir Afanasyevich Obruchev: 'The family was a colossus in the proper sense of the word.' We could also say that their origin goes back to the very masses of the people themselves. Talent, mother wit, and prowess were those particular forces that paved the Vavilovs' path in life. They may well be regarded as a coruscant example of how unfathomable the genius of the Russian people is.

THE HEARTH

Sergei Vavilov was born on the 24th of March 1891 in Moscow, in Bolshaya Presnya Street (now called Krasnaya Presnya Street), in the house of the Nyunins. The house, which was pulled down some time ago, was then let to Ivan Vavilov. Presently the Vavilovs moved to Vtoroi Nikolsky Pereulok (now Maly Tryokhgorny) into the house belonging to Aleksei Dubinin, a music teacher. The house was situated opposite the Church of St. Nicholas in Vagankovo and was in the neighbourhood of the University's astronomical observatory. In 1894 Ivan Vavilov became the owner of this house.

On the ground floor there were rooms for the parents and the children. Their grandmother Domna Vassilyevna and their aunt Yekaterina Mikhailovna lived in the attic. Little Sergei's favourite pastime was to visit them and there had hardly been a single visit when the boy did not prove himself to be a bit too naughty. All his life Sergei Vavilov cherished in his heart the memory of his old nanny Aksinya Semyonovna, her kindness and the innumerable fairy-tales.

Though the family was well provided for, little Sergei, as well as the other children, had never been treated more kindly than they deserved. There was nothing extravagant in the house: the articles of furniture were solid, though very simple, and one would look in vain to find a single luxurious object. The rooms were always clean and in perfect order. Both the senior members of the family and the children wore clothes that were in no way conspicuous. When the children came home after their classes, they had to change into clothes that were customary for home-wear: the boys wore black jackets, and it was usual to see the girls wear dark skirts and white blouses. At the beginning of summer the boys had their heads shaved.

Aleksandra Vavilova, who had the natural artistic taste, made every effort to inculcate in her children the appreciation of all that is beautiful. It would presumably be not erroneous to say that it was on her own initiative that in Sergei's room, next to the heavily laden bookcases, there hung the picture of Aleksandr Pushkin and the reproductions of Leonardo da Vinci's *Mona Lisa* and Raphael's *School of Athens*.

The parents had never used baby talk when speaking with their children. All forms of endearment were considered to be hazardous for the purpose of upbringing and were thus never encouraged. The appellations that were habitually used were: 'father', 'mother', 'Nikolai', 'Sergei', and so on. The children were taught to be modest, restrained, and unremittingly averse to indolence. It was precisely in those early years that these most valuable human qualities were perseveringly trained—the qualities that in later years would invariably cause admiration with all those who came into contact with the Vavilov brothers. The family was religious consistently observing the traditions. They all went to church together where they stood throughout the whole of matins and vespers, there being no benches to sit on in the Russian Orthodox Church. They observed the Lent and Easter, and regularly visited the graves of those whom they lovingly cherished in their memory, and prayed for the living and the dead. In his mature years, Sergei Vavilov used to recall the days of his early childhood: 'The world I lived in was permeated with the divine spirit. I implicitly believed all that was told me by my mother and my nanny Aksinya—everything about heaven and hell—and held in my mind the naive vision of God as an old man dwelling above the clouds.'

Aleksandra Vavilova gave her children all the independence they required. They did their homework without anyone's help, chose for themselves the books they wanted to read, and organized their own recreation. Though a believer herself, Aleksandra Vavilova expressed a markedly tolerant attitude to the fact that with time her children lost any interest in the church. Both she and her husband thought it was a fallacy to be too persuasive to their children as far as their future careers were concerned. On the whole, there was as little edification on their part as possible.

The father was a difficult person. In her reminiscences A. Tupikova wrote: 'I had no more than a glimpse of Ivan Vavilov on several occasions. He was always busy and had rarely been at home. From what his relatives said I learned that he was a man of enormous prowess and will-power. He had a harsh temper, and was very strict and even despotic in the family'. When he was out, his wife spoke of him as the 'Master'.

Many years later in one of his letters to his wife, Nikolai Vavilov wrote: 'In my childhood and youth there were many a day that were marked with anguish. The family as was customary with those in trade lived in no harmony, and there were times when the situation seemed almost unbearable. But all that is in the past, and to quote Pushkin we might as well say, "Without an evil thought in our minds, with gratitude for all the good will pay." And somehow one remembers more the good than the bad.'

Aleksandra Vavilova used Leo Tolstoy's book for beginners *The Alphabet* to teach her son Sergei the rudiments of reading. At the age of seven he was sent to a private primary school owned by the Voiloshnikov sisters. The school was situated in Malaya Gruzinskaya Street. Very soon it dawned upon the child that learning was no easy matter at all.

In recalling those years Sergei Vavilov wrote: 'I remember my first difficulties in science. What I could not possibly cope with at the outset of my studies in arithmetic was addition. Never in my life (and even now) could I stand the idea of "committing anything into my memory" rather than "to get to the bottom of it all". The confrontation I had with arithmetic was its first most coherent manifestation. I have managed to understand that, though I must say that I have never been able to become a good mathematician.'

At school Sergei was taught penmanship, grammar, arithmetic, and religion, as well as German and French. His success in each of these subjects was moderate. But what Sergei did like was books. In his own room at home he made a bookshelf where he kept one-volume works of Pushkin and Lermontov—the authors whom he read daily.

In 1901 the boy was ten. Wishing that Sergei become a businessman, as was the case with Nikolai some time before, Ivan Vavilov decided to send his younger son to the Moscow Commercial School which occupied the Eropkin Mansion in Ostozhenka. The first thing that was necessary to do was to take the entrance examinations. Sergei managed to do that though with no particularly great success. But what pleased the boy most of all was that he received the right to wear the uniform of commercial school which had been his pet day-dream for a long time, mainly because his elder brother wore the same,

The school was far from their home and the brothers were taken there in a horse-driven carriage.

The Commercial School, founded in 1803, was one of the best middle schools in Moscow. Those who completed their course of studies there often succeeded in becoming prominent men of industry. The school provided its pupils with practical knowledge. Though Latin and Greek were not in the curriculum, ample facilities were allotted to the study of such subjects as: physics, chemistry, biology, and mineralogy, as well as law, political economy, book-keeping, and business arithmetic. Particular stress was laid on the study of the main European languages—German, English, and French, though the Russian language, literature, history, geography, and mathematics did in no way remain unheeded.

The school was rich enough since most of its funds came from the donations of merchants' societies and individuals. This gave it every opportunity to have well-equipped laboratories where the pupils could apply their theoretical knowledge in physics, chemistry, and technology in practice. The school also took pride in its copious collections of minerals, herbaria, and the latest instruments for the demonstration of experiments in physics and chemistry. According to what Sergei Vavilov used to say later, there were not many higher educational institutes that could boast of the same.

The staff was also well qualified. Some of the subjects were taught by the lecturers from the university and institutes. Among them mention could be made of Ivan Alekseevich Artobolevsky, the one who became a professor of the Petrovskaya Agricultural Academy and who was the father of Academician Ivan Ivanovich Artobolevsky, who helped Sergei Vavilov in his future work on the propagation of political and scientific knowledge.

The school did everything to encourage a respectful attitude to its pupils. Beginning with the fourth term, the teachers had to use the personal pronoun in the plural instead of the word 'thou' which still remains customary when the adults speak to children.

It goes without saying that the school did have its own problems. The learning of foreign languages was by far not perfect. 'The fact was that foreign languages were not taken seriously at school. They were regarded as sheer nonsense that was meant to while away the time,'

Vavilov used to say with bitterness many years later. 'On the whole, an enormous amount of time was allotted to the study of a particular foreign language. Classes were conducted by native speakers of German, French, or English. But the results remained to be very poor. This state of affairs, which could hardly be accounted for, had a deplorable effect on the future careers of all of us. I must repeat, however, that the fault was ours and not that of the teachers. We boys simply did not have enough common sense to understand the vital importance of foreign languages. In any case, the Commercial School availed itself of all the means to promote the teaching of languages: only those of the foreigners who were highly qualified as language-teachers were made members of the staff. The tutors and guardians were also mostly foreigners, and it was assumed that they would use their own languages in communicating with the pupils'. In his later years Vavilov had to make up for the gap in his knowledge of foreign languages quite on his own.

One could hardly say that there were no problems with mathematics, physics, history, and political economy. Classes in mathematics were a dull procedure that lacked any inspiration. Sergei had no propensity for mathematics at all. '... I scraped through my examinations and came to the University with no knowledge of mathematics to speak of. It was a sad fact that had considerably hampered my future progress.'

At the beginning of his school days Sergei proved to be a lackadaisical pupil, showing hardly any interest in some of the subjects that were taught there. This attitude could not but incur the wrath of his parents. Aleksandr Ipatyev, basing on what he had heard from his mother Aleksandra Ivanovna and his grandmother Aleksandra Mikhailovna, wrote in his reminiscences: 'Nikolai and Lydia did very well at school, and in this respect made their parents feel happy and take pride in them. Things were quite different with Sergei. My grandfather Ivan Vavilov often thrashed him for indolence and bad marks. On the other hand, we would undoubtedly err in underestimating Sergei's talent for physics—the subject in which he later attained the acme of success—in the days when he was still a child. With the help of the ink that was called 'Smert' (death) he aptly forged his school-report, with the result that the bad marks were changed to the excellent

ones. And when the counterfeit proved to be a failure and thrashing was in the offing, he took the necessary precautions to palliate the harmful effect of his parent's wrath by inserting a piece of cardboard in the appropriate place of his trousers. In the mature period of his life Sergei Vavilov himself did not deny those "experiments in physics" in the days of his childhood.'

The sisters Aleksandra and Lydia had music lessons with a teacher who came to their house especially for that purpose. The boys regarded such lessons as something beyond their dignity. Sergei, however, had a wonderful ear for music and began to understand and appreciate it at a very early age. There were whole operas that he knew by heart and it was not infrequent that he sang tunes from them.

From his early childhood Sergei was drawn to the study of nature. He was fond of reading and looking through books about animals and birds, and he collected dry leaves and herbs, often astounding others with his diverse knowledge of the life of animals and plants. Later he made the following entry in his diary: 'I love nature, but what I require of it is no more than solitude and the beauty that does not interfere with my meditations.'

Though indifferent to many subjects that formed the school's curriculum and were thus compulsory, he showed no minor interest in the study of physics and chemistry. He was particularly keen on the laboratory experiments that were supplemented with the explanations given by the teachers, and he was eager to reproduce this or that experiment himself. This wish received the support of Sergei's elder brother Nikolai who had great authority with the boy.

Meanwhile, their father's business was rapidly flourishing. In 1905 Ivan Vavilov sold his house in Nikolsky Lane and bought an old wooden mansion with two small outbuildings in Srednyaya Presnya (now it is Zamorenov Street). The house itself was pulled down in 1924. The house had an attic and eleven rooms. This is what Sergei Vavilov later wrote about it: 'The house was one century old and had once belonged to some nobleman. The interior looked particularly impressive with a row of pillars, ornamented walls, a huge hall, and the doors made of mahogany.'

The hall had been divided into three rooms and thus

made a bedroom for the parents and two rooms for the boys. Sergei had the smallest of the two. Someone had hung in it the pictures of Nikolai Gavrilovich Chernyshevsky, of a Member of the St. Petersburg Union for the Liberation of the Working-Class Ivan Kalyaev, who was executed in May 1905 in the Shlisselburg Prison, and that of Maria Aleksandrovna Spiridonova who played a prominent part in the history of the Russian Revolution and who at that time was exiled to Nerchinsk for an indefinite period of time.

The house was surrounded with a neglected but a very good apple-orchard, a stable, and other small buildings that were meant to be used for various household purposes. There was also a small barn, which the two brothers did not hesitate to utilize for their experiments.

Ivan Vavilov was averse to parsimony when the money was intended for the education of his children. There were many books in the house, and the father had never grudged paying for the books in which his children were interested. The same could be said of all the expenses that were connected with the boys' passion for experimentation. Sergei Vavilov recalled how he had begun to collect jars containing chemicals, spirit-lamps, burners, phials, and retorts. 'I had a large shelf filled with preparations (fifty of them) that I bought at the chemist's shop owned by Ferrein with the money that was given to me. Now I may well say that the road to Tryndin for the purchase of containers, and to Ferrein for the pure substances had been trodden by me ever since I was fourteen.'

The famous future Soviet crystallographer Academician Alexei Vassilyevich Shubnikov was of the same age as Nikolai Vavilov, and at that time the two boys studied at one and the same school. In the sixth form it took Alexei Shubnikov no small pains and no less financial resources to construct an electrophorus for himself. He was exceedingly glad that his brainchild issued five-centimetre long sparks and was always willing to show it to all those anxious to see it work.

This news could not but reach the ears of the junior-class pupil Sergei Vavilov, who wasted no time in asking Shubnikov to make exactly the same machine for himself. The remuneration of the five roubles that Aleksei received was the sum that was beyond even the dream of avarice. In two weeks' time, Sergei became the fortu-

nate owner of the electrophorus that was of great service to him in his experiments.

What can be said of the elder brother's influence on Sergei? The four-year age difference between the brothers was particularly felt in their childhood. Nikolai was always willing to patronize his little brother. He was brave, strong, vigorous and had an enormous will-power. He never hesitated to retaliate against the offender and was invariably in a position to defend his younger brother who lacked the required prowess.

All the years that followed saw Nikolai and Sergei closely attached to each other, rendering immediate and unswerving support when necessary. In a letter from the USA dated 1921 Nikolai Vavilov wrote: 'I got a book for Sergei which he will appreciate—it contains the accounts of all the physicists on the most recent research. It has just been published. I am not sending it by post for fear that it might get lost. It costs as much as 6 dollars, and it has something that I would like to read myself.' These words speak eloquent enough of how much Nikolai cared for his brother, how fully aware he was of all that Sergei was doing, and the affinity of their scientific interests in spite of the difference in their professions.

Professor Fatikh Bakhteev recalled the following: At an evening party Nikolai Vavilov went to telephone his brother saying, 'I wonder how Sergei is getting along?' Later Bakhteev learned that no matter how late Nikolai came home he never failed to get in touch with his brother over the telephone and there invariably ensued a longish talk that took place practically every night. Nikolai was of a very high opinion of his brother's talent and often used to say, 'How can one possibly compare me with Sergei!'

The brothers, though they had much in common and were great friends, were nevertheless quite different people. Professor Eduard Shkolsky said to the author of the present book that in his youth Sergei had but little interest in politics. He spoke incessantly of physics alone. Nikolai, however, was always interested in the latest events and could easily get to the bottom of their sum and substance. Once, shortly after the October Revolution, Shkolsky and Vavilov were at one of their acquaintances, where the discussions concerning the situation in the country took place. Most of the disputants

were inclined to believe that what had occurred in Russia was no more than an insurrection that was bound to be suppressed and that everything would take its old course again! Nikolai, however, ardently supported the idea that a revolution, and not merely an uprising, was occurring and that every single patriot should take its side and actively help his people.

Sergei's world outlook as a natural scientist was greatly indebted for its formation to the public lectures that were given at the Polytechnical Museum, which he attended together with his brother. This establishment was founded in Moscow in 1872 by a society that took particular interest in the natural sciences, anthropology, and ethnography. Those present were fortunate to hear the popular science lectures delivered by many outstanding scientists of those days. Among them were the physicist Aleksandr Stoletov, 'the father of Russian aviation' Nikolai Zhukovsky, the physiologist Kliment Timiryazev, the specialist in soil sciences Vassili Williams, and many others.

What had a particular effect on the two brothers was the speeches of the naturalist and revolutionary Nikolai Morozov, who had just been set free after the Revolution of 1905 from Shlisselburg Prison where he had stayed in durance for twenty-four years. Sergei Ivanovich wrote: 'I still remember N. Morozov's passionate words in 1906... and how they inspired the youth in those days.'

When Sergei Vavilov became a famous scientist, he often availed himself of the opportunity to stand before the public at the Polytechnical Museum and speak of the latest achievements in physics.

The lectures at the Polytechnical Museum were not infrequently accompanied by the demonstration of experiments, which were followed suit by the boy himself in his own barn. He gradually began to experiment on his own, thus trying to understand some of the phenomena that were not clear to him. Of course, there was no real system to the arrangement of these experiments. When a certain effect came into his view, the boy started thinking of its origin and contrived experiments that would substantiate his own conjectures.

At one time Sergei was genuinely interested in botany. He acquainted himself with the classification of plants and collected no small herbarium. What seemed to be eye-striking to him was that many spring flowers were

yellow. He tried to interpret the phenomenon in which he became interested and began studying the works of K. Timiryazev. Together with his brother he tried to find out whether the frog continued to live in winter, and carried out some microbiological experiments.

When he was in his seventh year at school, Sergei discovered that a rubber comb charged by means of friction against the woolen trousers of his uniform was apt to lose its electric charge when confronted with the heat flow coming from the glass cover of a kerosene lamp. The explanation of this phenomenon furnished by his teacher Aleksandr Masing seemed to him to be quite untenable, and the boy began to avidly study the fundamental treatise of Sir Joseph John Thomson on the kinetic theory. At long last he found out that what lay behind the phenomenon he had discovered was the ionization of heated gas.

'By the time I was fifteen I had already become a mature naturalist with a wide scope of interests and a vast field of research lying before me,' Sergei Vavilov would recall. One more instance from his reminiscences reads: 'With A. Masing in my way I was still gradually becoming a physicist... I was acquiring the knowledge in physics entirely on my own.'

With time Sergei was becoming more infatuated with physics, doing a great deal of reading and finding himself absorbed in his favourite subject. In the eighth form, which was the last year at school, he made his first report on a scientific subject. It was called 'Radioactivity and the structure of the atom'. Its author proved to possess no minor erudition and a profound knowledge of the subject under discussion. The report was a great success.

As compared with many of his schoolmates Sergei went far ahead of them. In his diary of 1909 he made the following entry about his school: 'It is alien to me and remains cold and unpleasant. Why should I bother myself about their troubles, lack of order, and the reluctant teachers. All is nothing in contrast with the brainless and stupid pupils who are no more than menials of the lowest rank.' Commenting on what he wrote himself Vavilov made the next note: 'I think that all this is an exaggeration, though the greater part of it is true.'

The revolution of 1905 produced a great impression on the Vavilov brothers. It was exactly the period when the

family moved to Srednyaya Presnya and found themselves amidst the events that were then taking place. With their own eyes the children saw the armed uprising of the workers from Tryokhgorka and its consequent drowning in blood.

In what follows we have fragments of Sergei Vavilov's reminiscences: 'I am fourteen. What stands before me is a blurred spot rather than the cognizance of what is happening. At school we play revolutionaries. I am writing a kind of charter for an imaginary circle and am concocting an article on socialism without understanding what it is all about... At home neither my father nor my mother can understand anything either. We are allowed to go wherever we like—to demonstrations and meetings. Bauman's funeral: the procession has engulfed the whole of Moscow... At home the sisters are seated at the grand piano, playing the tune of the song in honour of those who gave their lives away for the cause of the Revolution. Afterwards I frequently visited Bauman's grave in Vagankovskoye Cemetery... and always carried away with me a little flower or a small ribbon from out of the wreaths... The parents' attitude was that of non-interference... Our school was temporarily closed, and there began to appear barricades in the streets in the erection of which I took no small part. Some of the material of which they were made came from what was no longer our unimpaired fence... In addition to all this I tore up a calendar with the picture of the Czar's family... My mother was standing on the porch when a shell-splinter fell right beside her. I still keep it at my home in Leningrad... My brother Nikolai was nearly killed when he was running away from the police across the pond covered with ice close to the Gorbaty Most. The rebellion came to an end and was immediately followed by reprisals. I can still remember how the wounded were given shelter with us and in the houses next door to ours. Every effort was made to hide the pamphlets and leaflets... Houses were thoroughly searched too... I understood practically nothing in politics... and can only say that I hated those from the "black hundred" (the reactionary organization whose main function consisted in suppressing all that was progressive). However, my own attitude to what was going on was far from being coherent. I belonged to the left-wing movement,

I was actually one of those who were making barricades, I tore the pictures of the Czar into small bits, and hid the leaflets from the vigilant eye of the police... and yet all this was but child's play... My left-wing ideas and the concepts of democracy remained outside politics, without the scope of its rigidity and even cruelty (the objective necessity of which I always fully understood, though could hardly ever make a move towards its implementation in practice). Nowadays this is called 'spinelessness'. This is undoubtedly where my deeply-rooted non-affinity with any party finds its origin. I was frightened by the Revolution of 1905 and avidly took up the study of science, philosophy, and the arts. That was the state I was in at the advent of the year 1917.'

The fact remains, however, that the events that had taken place did to no minor extent foster the attitude of the Vavilov brothers towards the Soviet Power after the Great October Socialist Revolution which they unequivocally supported and to whose benefit they devoted all their selfless attainments.

Ever since Sergei was a child he had known a great many pieces of poetry by heart and could recite them with no minor skill. His most beloved poets were Pushkin, Baratynsky, Tyutchev, Fet, Blok, and Goethe. Of the prose writers, the boy particularly distinguished Dostoevsky. The compositions on literary subjects that Sergei wrote at school had invariably delighted his teachers. Sergei Ivanovich wrote: 'I can clearly remember how from my very first year at school I was beginning to be singled out among the others as the one possessing a particular trend of thought and propensity for literary studies.' In the years of his adolescence he became interested in philosophical problems, though he had never remained indifferent to the arts.

Following his brother's example, Sergei organized a club for the pupils in the fifth form, which had continued to function right up to the end of their course of studies at school. Those participating in the work of this club took part in the discussions of the reports on literature, arts, philosophy, and politics. Sergei had not only invariably presided over those meetings but also never failed to come up in the role of the main speaker. As an adult, he used to recall: 'It was I who had the lion's share of the work. I had to write reports on Tolstoi, Gogol, Tyut-

chev, Mach, the decadents, and suicides as a social phenomenon.'

No minor role in fostering Sergei's artistic taste was played by Ivan Evseev, his teacher of drawing and penmanship. He was a man who seemed to be quite lonely in his world. A preceptor by nature, he loved his pupils and saw the sum and substance of his life in their upbringing. Sergei wrote: 'He was an exceptional person whose influence on me as well as on many others could hardly be underestimated... He was one of those who ought to have monuments erected to them.. I became his real friend.'

Evseev regarded excursions as one of the means of aesthetic education. He thoroughly prepared himself for each of such occasions, and had preliminary talks with his pupils about the places they were to visit. When the sightseeing was over there usually took place an exchange of opinions to be followed by the making of elaborate notes on the excursion. This kind of work was regularly done by the pupils.

Later in his diary, which he kept when a young man, Sergei wrote: 'I was in Mikhailovskoye and Trigorskoye, at the very fount of Pushkin's lyre. Pushkin became a part of my own self—not like Goethe and Shakespeare—but my one and only dear to my heart Aleksandr Sergeevich. I know that this sounds exaggerated, but I can't help adoring Pushkin; his words have become a law with me. Amidst the banal humdrum... there stands Pushkin—the holy of holies of all that is beautiful and divine to a Russian heart.'

Then comes the exclamation: 'Pushkin is my eternal hope! Were I to be perishing, I should probably have the Gospel in one hand, while the other would most certainly grasp the product of Pushkin's genius.'

At school there were evening parties organized by Evseev himself. His young friends spoke of what interested them during the excursions and showed photographs. What particularly remained in Sergei's memory was the exhibition in the hall devoted to V. Zhukovsky and N. Gogol. It was carefully prepared by I. Evseev with the help of their headmaster Konstantin Kozyrev (Sergei then was in his first year at school). The exhibition became to be popular throughout Moscow, and the ten-year-old Vavilov did not hesitate to produce his first

literary essay, which was titled 'My impressions of the exhibition' and where there was no stint of such phrases as: 'The picture has impressed me most favourably.'

Evseev used to take his pupils to St. Petersburg, Kiev, Kostroma, Novgorod, Saratov, Yaroslavl, and the Crimea. He guided them around the museums and exhibitions in Moscow, thus providing the young ones with fascinatingly interesting comments on what they saw.

This is what Sergei Vavilov's whilom classmate Boris Sebentsev wrote in later years: 'I can readily imagine Sergei at the time when his adolescence was burgeoning into maturity. I clearly see him in the hall of the Institute* lecturing on his impressions of St. Vladimir's Cathedral in Kiev (it was after our excursion in either the seventh or the eighth form). He spoke with such ardour and artistic skill that those present could not but actually visualize Vasnetsov's icon of the *Blessed Virgin* cast off its nebula and come to life.'

Evseev's efforts were not in vain. 'He knew each one of his pupils perfectly well,' Sergei Vavilov used to recall, 'and even now at the age of sixty, they all remember what he had instilled in their hearts and minds (I learned this from quite a few of my quondam schoolmates).' Vavilov himself often astounded his acquaintances with his profound erudition in such domains of the arts as painting and architecture. There can hardly be any doubt that what lay at the bottom of his interest and love for the arts had in its time been inculcated by the persevering schoolmaster.

For the formation of his world outlook Sergei Vavilov was greatly indebted to Vladimir Ilyich Lenin's book *Materialism and Empiriocriticism*. The young man studied this work in 1909, with pencil in hand, when it was first published under the penname of V. Ilyin. There is every reason to believe that his acquaintance with this treatise had enhanced Sergei's lively interest in the philosophical problems of the natural sciences—a concern that remained undiminished for the rest of his life.

At the age of twelve, Sergei found himself absorbingly interested in rare books, and some time later he began collecting the classical works on the natural sciences.

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* The Usachev-Chernyaevsky Institute was a higher educational institution for women that was founded on private means.

He started frequenting the second-hand bookshops and book placers at the Kitaigorodskaya Wall in Moscow, in Sukharevskaya Street (now Kolkhoznaya Square), and in Mokhovaya Street (known today as Prospekt Marksa), where among heaps of what was regarded as wastepaper one could occasionally dig out a book of no minor value. Thus, his excavations proved to be extremely fruitful when he found *Experimenta nova...* by Otto von Guericke, containing the description of the experiments with the famous Magdeburg hemispheres, as well as one of the works of Michael Faraday signed by the author himself.

His love for books had never deserted him. Sergei Vavilov had collected a unique library comprising some thirty-seven thousand volumes. It contained a great number of the works by Pushkin, complete collections of all that had been created by the poets Fet and Tyutchev, and the innumerable editions of Goethe's *Faust* published in different years. The preponderant part of Vavilov's library included books on the history of the natural sciences, among which there were quite a few rare editions dating back to the beginning of the sixteenth century. He perused every single book that he acquired. His juvenile infatuation with the old editions encouraged what turned out to be a profound interest in the history of science.

When Sergei was nineteen he attempted to give an introspective analysis of himself in his diary. This entry was reproduced in full in the reminiscences that were written much later: 'Until the age of ten, before I was sent to school, I was a pusillanimous child, a lonely daydreamer disposed to mysticism. Up to my fifteenth birthday I had remained to be a mystic, dreaming of alchemy, miracles, sorcerers, doing a lot of useless reading, and continuing to be faithful to my religious beliefs. The year 1905 was the starting-point of my awareness, which in the stage of its inception was crude and weird. Then I tried to become a poet, a philosopher, a contemplator of the world, and had thus made myself conspicuous. I came to know, or to be more exact felt, both pessimism and optimism, joy as well as frustration, and "the religion of science". My first guide was the book by Mechnikov, but I was never interested in the life of any of my contemporaries, though I myself lived amidst what was virtually a seething cauldron.'

The young man, upon whom Nature had lavishly bestowed so many a gift, found it extremely difficult to choose his own path in life. The scope of what absorbed his mind was very great indeed. He was as indifferent to the carreer of a merchant as his elder brother had been when confronted with the choice of his profession. At long last he approached his parents with his decision to enter the Physics and Mathematics Faculty of Moscow University. His father was very much distressed. The hope that at least his younger son would take on the business had completely vanished. But, having already once experienced the obstinate resistance on the part of his son Nikolai to comply with his wish, he acceeded to Sergei's desire to pursue his own interests.

The realization of Sergei's plans had turned out to be a difficult problem. The Commercial School was a specialized educational establishment and its pupils were not granted a certificate that had the same validity as that issued by the schools providing a classical education. Thus, they were deprived of the right to enter the University, and Sergei had either to start working in his professional field or continue his studies at the Commercial Institute.

Those wishing to be matriculated at the University had to take a proficiency test in Latin that was wholly in conformity with the gymnasium syllabus. This circumstance had had a decisive effect upon Nikolai's career. At first his pet day-dream was to take up the study of medicine, but having no desire to spend his time on Latin, he entered the Petrovskaya Agricultural Academy. Sergei did not ignore his brother's experience: he rolled up his sleeves to tackle Latin on his own before it was too late. This called for no minor exertion. But his assiduity brought him success. The six-year gymnasium syllabus was covered within the period of only one year. In later years, his good knowledge of Latin enabled him to feel quite at home with the classical works of M. V. Lomonosov and Sir Isaac Newton in the original.

In June 1909 Sergei Vavilov completed his course of studies at the Commercial School with plenty of excellent marks in his certificate. The subjects in which his competence was assessed one mark below 'excellent' included German, French, and English, as well as mathematics and geography. Besides, he managed to succeed equally well

in Latin, the subject, as has been said, that was compulsory for the gymnasium pupils. Thus, the path to the University lay unhindered before him.

AT MOSCOW UNIVERSITY

In those years the University did not require that students take entrance exams. It sufficed for anyone wishing to become enrolled to produce a certificate testifying to that its bearer had received a classical secondary education. The tuition fees (50 roubles a term) were rather high, and students grants did not exist as such. Under such circumstances, the influx of undergraduates was markedly restricted.

In the autumn of 1909 Sergei Vavilov became a student in the Physics and Mathematics Faculty of Moscow University. The faculty covered a wide scope of specialities, and was divided into two main sections: the one concentrating on mathematics, and the other dealing with the natural and historical sciences. The mathematics division trained mathematicians, mechanics, physicists and astronomers, the second division trained chemists, biologists, geologists, and geographers. Sergei was interested in both physics and chemistry. Though he could not readily make up his mind at first, he finally decided to study physics and thus joined the department of mathematics.

For many years, the University had been struggling to attain an autonomous status. In 1863 regulations were adopted relaxing the government control over the University. The Rector and deans were to be elected, though the rector-elect had to be further confirmed by the Czar himself, while the deans, professors and lecturers were confirmed by the Minister of Education.

In 1884, frightened by the activity of revolutionary forces, and the students movement in particular, the czarist government succeeded in adopting a new set of rules that reduced the University's autonomy to nothing. The University lecturers were now selected entirely by the Minister of Education, while the young people desiring to study there were obliged to submit a special document certifying their political trustworthiness.

The 1905 revolution shook the foundation of czarism. Pretending to introduce social reforms, the Czar issued

a decree on the 27th of August, 1905, according to which the autonomy of the University was resuscitated. The maintenance of order at the University had now become the concern of its own administration.

Sergei Vavilov was very fortunate. At the beginning of the twentieth century, Moscow University prided itself on its staff-members, many of whom were celebrated scientists. The mathematicians included Nikolai Luzin, Dmitri Egorov, and Boleslav Mlodzeevsky; among those teaching the students mechanics were Nikolai Zhukovsky and Sergei Chaplygin; studies in astronomy were conducted by Vitold Tserasky, Sergei Blazhko and Pavel Shternberg. The physicists who must be specially mentioned were Nikolai Umov, Pyotr Lebedev, and Aleksandr Eikhenvald.

The other faculties had no less eminent lecturers. Among them were Kliment Timiryazev (botany), Nikolai Zelinsky and Ivan Kablukov (chemistry), Vladimir Vernadsky (mineralogy), Georgi Wulf (crystallography), Aleksei Pavlov (geology and paleontology), Dmitri Anuchin (geography, anthropology, ethnology and archaeology), and others. The lectures delivered by these eminent scientists had left an indelible imprint on the minds of the students, encouraged their allegiance to science, and promoted the burgeoning of their own insatiable love for scientific quests.

An excerpt from Sergei Vavilov's reminiscences follows: 'September 1909. The first time I have heard Lebedev's lecture. It was absolutely different from the other lectures at the University that we, the first-year students, avidly listened to, running from one faculty to another. What I heard now was the words of a scientist rather than those of a professor, and the content of the lecture was quite unusual. Lebedev was addressing the audience as if it consisted entirely of those who were likely to become scientists and was telling them what was exactly essential for the one wishing to do research in the field of physics. Emphasis was laid on the fact that it was not an easy task at all, though the concluding words were encouraging: "Poor is the soldier who does not want to be a general". The image of a physicist as well as what I derived from that first lecture could not be obliterated from my memory.'

Sergei did a lot of painstaking work to familiarize

himself with the subjects that were immediately connected with his future profession. He never failed to attend the lectures of Aleksandr Nekrasov on the theory of sound, those of Pyotr Lazarev dealing with the electronic theory, and many others. The young man began to take an active part in the public life. Only several months had passed before he was made responsible for the forthcoming Twelfth All-Russia Congress of Russian Naturalists and Physicians in Moscow.

The Congress was an event of great significance in the cultural life of the country. It took place from December 28, 1909 to January 6, 1910, and was headed by Dmitri Anuchin, Ivan Pavlov, and Professor Ivan Borgman of St. Petersburg University. The conferences were held in the lecture-rooms at the University, the Higher Technical School, and other educational establishments in Moscow. Over five thousand people took part in the work of the Congress with more than seven hundred reports submitted for discussion. The participants were given every opportunity to acquaint themselves with the experiments and exhibitions, and to take part in the excursions to the public establishments presenting special interest. At the physics section Pyotr Lebedev conducted a number of fascinating demonstrations and phenomena in physics, and in particular, reproduced Aleksandr Stoletov's experiments on the photoeffect.

This was where Sergei Vavilov saw and heard Aleksei Krylov, Dmitri Rozhansky, Abram Ioffe, and other outstanding scientists of Russia. Pyotr Lebedev enjoyed particularly great success. In later years Vavilov wrote: 'January 1910. The Twelfth Congress of Naturalists and Physicians. The evening session held at the physics section. On the agenda we have P. Lebedev's report on the "Effect of Light Pressure Upon Gases". Never had there been so concentrated an audience as the one that hung on to every word pronounced by the orator when he was telling his listeners about an experiment that seemed to be of insurmountable difficulty, and never had I later heard a more tumultuous storm of applause that greeted the final words of what was a dry account of scientific research. It was genuinely a well-deserved triumph for the great physicist and experimenter, who has managed to carry out an experiment that could hardly have been tackled by anyone else in the world.'

Vavilov was fortunate to be introduced to Lebedev and to begin working under him when the latter was at the acme of popularity. But the years of the eminent scientist were numbered: he had no more than about two-and-a-half years to live.

The biographies of the two scientists had much in common. Lebedev was also born in Moscow and came from the family of a merchant. He was born in 1866 and had a similar cultural background. The certificate he received on leaving the private professional school also did not give him the right to enter the University, and he became a student of the Bauman Higher Technical School (MVTU im. Baumana in Moscow). Already at that time Lebedev wrote that he had a great desire 'to become either a researcher or a discoverer'. In 1887 he went to France to study physics at Strasbourg University. There he developed the theory of comet tails, thus proving that their deviation was caused by the pressure of light.

In 1891 Lebedev defended his dissertation 'On the variation of dielectric constants of vapours and the Mosotti-Clausius's theory of dielectrics'. The Doctor of Philosophy degree was conferred upon him. On his return to Moscow he began to work with Professor Stoletov at the University. In spite of the difficulties Lebedev managed to organize a laboratory where he conducted his research on the effect of hydrodynamic, acoustic, and electric waves on resonators, as a result of which his idea concerning the pressure of light on molecules was fully substantiated. In 1899, for his work the Scientific Council of the University conferred upon him the degree of Doctor of Physical and Mathematical sciences without any preliminary defence of the Master's dissertation, which was a prerequisite in almost all other cases. In 1900 he was appointed a professor of the University.

Having overcome enormous experimental difficulties the scientist proved the influence of light pressure upon solid bodies. In May 1899 he gave a tentative account of his experiments in Lausanne (Switzerland), and in August 1900 he announced his discovery at the International Congress of Physicists in Paris. Lebedev's report produced an overwhelming impression upon all those present.

In 1865 the English physicist James Maxwell proposed the electromagnetic theory of light according to which

the high-speed transverse electromagnetic waves propagate at the fantastic velocity of approximately 300 000 kilometres per second. What proved to be an important corollary of this theory was the assumption that light had to exert pressure on the bodies that it confronted in its propagation.

In the experiments carried out by Lebedev, Maxwell's theory had found a cogent experimental substantiation. At that time the famous English physicist William Thomson told Kliment Timiryazev: 'I suppose you know that all my life I have been against Maxwell and his ideas of light pressure, which I could not possibly regard as tenable, and it was only your Lebedev who has made me surrender to his experiments.' Lebedev was awarded a prize by the Russian Academy of Sciences and elected a corresponding member.

The problem that he then began to solve was of much greater complexity. It was connected with the determination of the pressure of light on gases. For eight years he worked on a design for a contrivance that would make it possible to register the minutest effect. In 1907, at the First Mendeleev General and Applied Chemistry Congress, Lebedev announced a new success—the experimental proof that light exerted pressure on gases. Among those who heard that report was Sergei Vavilov.

Pyotr Lebedev is famous not only for his fundamental studies. He also went down in the history of science as the founder of the first school of physicists in Russia. From the very beginning of his activity at Moscow University he had made every effort to involve undergraduates capable of doing research in his investigations. This small room allowed a group of not more than five or six people. The person who helped to substantially improve the facilities for doing research in physics at the University was Professor Umov.

Nikolai Umov, an acknowledged authority in the field of theoretical and experimental physics, came up with the idea of establishing a Physics Institute at Moscow University. In 1904 the building that was to accommodate the Institute was completed. Lebedev received a large basement room, the greater part of which was allotted to a mechanical workshop. He was also fortunate to have two big rooms on the first floor. The total area of the laboratory exceeded 400 square metres. Now there was

every opportunity to attract more of those students who had successfully coped with the syllabus in the practical and theoretical aspects of the course in general physics to scientific research. Lebedev was convinced that the formation of a scientist should be taken care of at the very inception of his studies. This was why there were even second- and third-year students working in his laboratory.

One of these students was Pyotr Lazarev who was destined to become a scientist of great renown. It was he who became the author of fundamental studies in such domains as molecular physics, photochemistry, biophysics, and theoretical geophysics. In 1896 he entered the faculty of medicine at Moscow University and graduated from it in 1901 with honours and a licence to practice. Within a year Lazarev passed the examinations for the degree of Doctor of Medicine and began working as an assistant at the Clinic of Ear, Nose and Throat Diseases of the medical faculty of Moscow University.

When he was still a first-year student, Lazarev used to attend the lectures given by Professor Umov and those of Lebedev who was then a reader*. He was most favourably impressed with them. The young man became so interested in physics that he managed to receive the permission from the Ministry of Education to take all the examinations covering the course of studies in the physics and mathematics faculty, and in 1903, Lazarev succeeded in making his dream come true. He regularly attended Lebedev's tutorials and conducted research on his own in Lebedev's laboratory. The latter offered him the job of an assistant, and very soon Lazarev became Lebedev's immediate associate and a great friend.

Those who began their work in 'Lebedev's basement room' included Torichan Kravets, Kliment Timiryazev, Vladimir Zernov, Nikolai Kaptsov, Vyacheslav Romanov, Nikolai Andreev, Pyotr Belikov, Anatoli Mlodzeevsky, Sergei Rzhevkin, Vladimir Arkadyev, Nikolai Shchodro, and other famous scientists. By 1910, Lebedev's team of scientists had already included up to thirty people.

The student Vavilov had an ardent desire to become a member of this remarkable group of scientists. He was

* In the higher educational establishments of Russia the post of a reader could be held by those who had a Master's degree and who delivered optional courses of lectures.

particularly keen on the practical studies in physics, accomplished all that was required of him ahead of schedule, and successfully passed his examination in general physics with Lebedev. And it was to him that he appealed with the request to work in his laboratory. Lebedev granted him permission, and thus the second-year student Vavilov became a participant in unprecedented scientific research.

At that time Lebedev's health had markedly deteriorated. He suffered from angina pectoris (chest pain), a disease that was rapidly progressing, and he hardly ever left the premises of the Institute where his flat was located. Some of his commitments were taken on by the University's reader Lazarev. It was then that Pyotr Lazarev became Vavilov's scientific adviser.

The Lebedev school had its own traditions. Its leader encouraged the independence and initiative of those working under him. Each of his pupils had a key to the laboratory, the workshop and the library, and could work there at any time that suited him. The members of the team were always in touch with one another. They always knew what their colleagues were doing and could invariably offer their own criticism. It was Lebedev's firm belief that every single experiment should be preceded by thorough consideration. Those working in the laboratory were obliged to be *au courant* with the state-of-the-art and allot time to the interpretation of their experimental results. Lebedev taught his pupils that even the most perfect apparatus could not generate any new ideas in physics and that everything depended entirely on those who were handling it.

Levedev was also extremely particular about how the articles intended for publication were prepared. He made those responsible for them rewrite the manuscripts five or six times until precision and coherence were attained. He was averse to frequent publications, and left only twenty-two articles after his death. This is due not only to the tremendous difficulties that were connected with experimentation, but also to the fact that the author was elaborate in the extreme as far as the presentation of the results was concerned.

Lebedev demanded that the experimental part of the research should be done by his pupils entirely on their own. This presupposed that for a month or two each one of them

had to do practical work in the University's workshop under the guidance of the foreman P. Gromov. The pupils worked as fitters, turners, joiners, mechanics, glass-blowers, and every one of them was responsible for making the laboratory apparatus that was required. The 'Gromov University' enabled the young people to acquire the necessary technical skills.

From 1901 and with Lebedev at the head, the small room of the Stoletov Library on the second floor of the Physics Institute witnessed the first weekly science colloquium in Russia. Here, everything was conducted on democratic principles. Any one of those present at such meetings had the right to interrupt the speaker and ask him to clarify his point. The eminent scientist and the undergraduate participating in such discussions enjoyed exactly the same rights. What Lebedev demanded of his pupils was that they should never take anything for granted and that they should never bow before someone superior to them in rank. The discussions that were held there were so absorbing that they could not but draw the attention of the professors of other departments. Those who attended the sessions included K. Timiryazev, N. Luzin, S. Blazhko, and G. Wulf. Some time later the Lebedev colloquium gave rise to the creation of the Moscow Society of Physicists.

Lebedev was not fond of giving lectures, and whenever he was obliged to engage himself in this kind of activity, he made every effort to apply to higher mathematics as infrequently as possible. He invariably accompanied his lecture with demonstrations that had been elaborately prepared beforehand. The special course 'New Works on Physical Studies' which Lebedev delivered in the smaller lecture room for the seniors in physics was of great significance. The lectures in this course presented a critical review of what was published in physical periodicals outside Russia. His brilliant knowledge of the history of each problem under discussion had never failed to amaze his listeners.

The year 1910 was marked by un upsurge in the student revolutionary movement. The fear of the student unrest caused the czarist government to send a police squad to the University 'to maintain law and order' in flagrant violation of the University's autonomy. In January 1911 the Minister of Education, Lev Kasso, issued a special

order obliging the rector of the University to call the police during any recurrence of the 'disturbances'.

Aware of their total inability to alter the situation, the Rector Aleksandr Manuylov, his assistant Mikhail Menzbir, and the Pro-rector P. Minakov informed the University's council of their intention to resign. On January 28, 1911 the resolution was adopted by the council in which it was said that what Kasso demanded of them 'made it impossible for the elected administration of the University to continue performing what was incumbent upon them'. Kasso dismissed the three who wished to resign.

The arbitrary decisions of the Minister had brought about a storm of indignation among the progressive-minded professors and lecturers. One hundred and thirty professors, readers, and lecturers (over one-third of the teaching staff) left the University in protest. They included G. Wulf, N. Zhukovsky, N. Zelinsky, P. Lazarev, P. Lebedev, K. Timiryazev, N. Umov, V. Tserasky, and A. Eikhenvald. To quote Timiryazev, there now reigned supreme at the University 'the atmosphere of abominable desolation'. Lebedev's resignation could only have been regarded as a catastrophe since, as compared with a large number of other professors and lecturers, he had never had any part-time job anywhere else and was not eligible to receive a pension. Moreover, the flat he occupied belonged to the University and he was now destined to have no home at all. But what aggravated him most was the fate of his laboratory and the school of physicists that he had founded on his own initiative. The position he found himself in had a deteriorating effect on his health. And yet, according to what Torichan Kravets said, 'This was one more example he presented to his pupils—the example of unblemished honour and civic duty.'

The educational establishment that rendered its support to Lebedev's laboratory was A. Shanyavsky Moscow City University, where P. Lazarev held the part-time post of Head of the Physics Department. The University had been founded with the private funds of the liberal-minded general Alfons Shanyavsky, who had donated two hundred thousand roubles to have it organized. It began functioning in 1908 in Volkhonka in the building where the Golitsin Agricultural Courses had formerly been accommodated. The University was headed by K. Timiryazev.

Many young physicists from Lebedev's laboratory were invited to work in the physics laboratory of the newly-organized educational institution. They were N. Andreev, D. Galanin, D. Sakharov, A. Kalashnikov, S. Rzhevkin, E. Shpolsky, T. Molodyi, and others, including S. Vavilov.

At that time Lebedev received two job offers: one that came from the Director of the St. Petersburg Board of Weights and Measures, Nikolai Egorov, and the other from Professor Svante August Arrenius of the Nobel Institute in Stockholm. As a patriot, Lebedev deemed it impossible to desert his pupils and go abroad. St. Petersburg did not appeal to him either, since most of his pupils were in Moscow.

Lebedev received financial aid from the Kh. Ledentsov Society, which promoted success in experimental sciences and their practical application. This organization was founded in 1909 at both Moscow University and the Moscow Technical School with the funds that were provided by Kh. Ledentsov, a millionaire industrialist, who bequeathed two million roubles for the development of research in the natural sciences and technology in Russia. The Society was managed by N. Umov. It had a major influence on the development of a number of highly important undertakings in Russia. Thus, it rendered material support to N. Zhukovsky's aerodynamic laboratory, allotted funds to the construction of the three-storeyed building where I. Pavlov could conduct his physiological experiments, and so on.

At Lebedev's request, the Society granted him fifteen thousand roubles. With this sum of money it became possible to rent two flats in the basement of a profitable house in Myortvyi Pereulok (meaning Dead Lane)—nowadays known as Pereulok Ostrovskogo. They consisted of nine small rooms: one of them was for the mechanic; Lebedev's study and library were located in two other rooms, and the rest served the purposes of the laboratory. Lebedev and Lazarev also had rooms for their personal use on the upper floors of the house. Thus, Lebedev's new laboratory became part of A. Shanyavsky University.

Pyotr Lebedev was obliged to go abroad for medical treatment. In his absence, and under the direction of Lazarev, the young people spared no effort to organize the new laboratory. Little booths for individual work

were made of veneering; tables, shelves, and original installations appeared, they themselves doing the work of turners and glassblowers. Among them was the student Vavilov. In less than three months the laboratory was quite ready. In the first half of August 1911 Lebedev received the good news from Lazarev. Lebedev became anxious to return to Moscow. In his letter to Lazarev he wrote: 'Presently I shall be coming back to Moscow and shall wholeheartedly make certain that you and I are doing something of vital importance on our little street the name of which has a moribund implication.'

Lebedev returned to Moscow in September; however, the state of his health was aggravated. In February 1912 he took to his bed and on the first of March he passed away. Pyotr Lebedev's death was a shock to scientists throughout the whole world. At that time Nikolai Vavilov wrote, 'What has happened is a grievous event for Russian science.'

The greatest monument to Lebedev was the first school of Russian physicists that was created as a result of his own indefatigable activity.

Many years had passed before Sergei Vavilov wrote the following words: 'On a level with M. Lomonosov, P. Lebedev is one of the most remarkable men in the history of Russian physics. He was the first to organize collective scientific research in physics and research laboratories on such an impressive scale that they have become an example to be followed by present-day scientific institutes.'

There can hardly be any doubt that Sergei Vavilov was greatly indebted to Lebedev for his high scientific culture, style of work, and sociability. It was on Vavilov's suggestion that the Physics Institute of the USSR Academy of Sciences—the centre of physical studies in the country—was named after Lebedev. A bust of the scientist now stands in front of the Institute, and a large bronze monument to Lebedev has also been erected outside the Physics Faculty of the Lomonosov Moscow University on the Lenin Hills. The street on which the University borders has received the name of this great scientist, and a plaque bearing the name of Lebedev can be seen on the wall of the old building of the University in the centre of the capital.

In 'Lebedev's basement' in Mokhovaya (now called Prospekt Marksa) Sergei Vavilov worked for a little over

three months. During that period he underwent practical training in the workshop, attended tutorials and was assigned a research topic by Lazarev. He acquainted himself with the literature on the subject, and with no help from outside designed his own experimental set-up.

But it was in Myortvyi Pereulok that Sergei completed his first scientific investigation. Having organized a student circle, which studied the scientific literature and wishing to help his friend E. Shpolsky, he studied special materials and wrote the critical essay 'The photometry of sources of different colours'. In it Sergei gave a detailed analysis of the problem pertaining to the possible accuracy of photometric comparison of the sources of light of different colours and subjected to criticism a number of analyses that had previously been done. Vavilov, who was then only an undergraduate, suggested that there was a difference in the elements of the human eye's retina responsible for the perception of brightness and light. Later, this idea was experimentally substantiated. Presumably, while writing this report Sergei conceived a profound interest in the problems related to physiological optics—a subject that remained his lifelong concern.

S. Rzhevkin's reminiscences referring to this particular period of Vavilov's life contain some very interesting, though unexpected, facts. According to S. N. Rzhevkin, within the walls of the laboratory in Myortvyi Pereulok Vavilov had acquired his first experience in the organization of the physics colloquium in which all the young physicists took part. There is also a sufficient amount of information on the splendidly delivered and highly instructive speeches made by Vavilov in the last twenty years of his life.

It seems that Vavilov had not been in command of the art of rhetoric at the outset of his career. Recalling his first scientific reports, Rzhevkin mentioned that in those years Vavilov had been a very poor orator: he spoke incoherently, and frequently the purport of his message escaped his listeners. But what appealed to his friends most of all was his erudition, his ability to prompt the ways along which the research should be conducted and his desire to create an atmosphere of collective scientific endeavour. In the years to follow through practice and by making every possible effort Vavilov attained absolute perfection in the art of speaking.

At that time Vavilov's scientific adviser Pyotr Lazarev was working on his doctoral dissertation which was on the complicated processes of the photochemical decolorization of dyes. Wishing to analyze the nature of these processes Lazarev suggested that his pupil should study the decolorization of dyes due to heat rather than due to light and compare it with the processes of photochemical decolorization. Sergei became absorbed in this subject and created his own original experimental set-up.

Vavilov chose five dyes of the cyanine series for his analysis. The dyes were dissolved in a mixture of alcohol and collodion. A thin layer of the solution was put on the glass coverings of the photoplates that were then dried in a dark room. What was formed on the plates was a thin film of the dye. For the study of those changes that took place during heating the widely spread instrument called the Koenig-Martin's spectrophotometer was used.

After careful measurements were made, Vavilov discovered marked differences in the decolorization of dyes under the activity of light and heat. He established that the photochemical process depended little on temperature. It occurred that the thermal decolorization of dyes in darkness was three times more intense than the photochemical decolorization under conditions of increased temperature. The experimenter had accomplished a contrastive analysis pertaining to the kinetics of the thermal decolorization of various dyes. The kinetics proved to be markedly dissimilar.

The report 'The thermal decolorization of dyes' was Sergei Vavilov's first major achievement in science. This was where his propensity for subtle scientific research had found its expression. As far as its experimental level and profundity of theoretical study were concerned it became on a par with the best works of Lebedev's school. According to T. Kravets, it was owing to Vavilov's first publication that 'he had joined the ranks of physicists at work, and, in particular, the province of those ideas that were propounded by Lebedev and Lazarev'.

Vavilov's article was published in 1914. Its second and more complete version came out in 1918. The research had brought its author official recognition, in 1915; a society for those interested in the natural sciences, anthropology and ethnography at Moscow University awarded him a gold medal.

Sergei Vavilov knew how to alternate periods of work and rest. This was also in the spirit of those traditions that were established at Lebedev's school. Lebedev was a versatile person himself: he loved music, often attended concerts and theatres, and at the same time took a lively interest in painting and literature. He was also an enthusiastic mountain climber and encouraged his pupils to acquire diverse interests. The last colloquium session before the holidays was spent on showing slides and discussing the more fascinating itineraries.

In his school years, Sergei always had problems with physical education classes. 'I simply could not cope with what was required of me,' he later recalled: 'I would come an impressive purler with a bleeding nose when trying to do the horizontal bars, the vaulting-horse never failed to remain an insurmountable barrier for me and pole-climbing brought exactly the same results. In my life I have never experienced the least passion for sport, which could be well accounted for by my congenital inability to show any prowess in this field of human activity, i.e. by my lack of biceps. What served as my physical training in the years to come was war and horseback riding.'

When a student, Sergei took great interest in travelling. During his summer holidays he twice visited Italy, toured Austria and Switzerland. When he stayed abroad he devoted a great deal of time to the study of the arts—painting, sculpture, and architecture—which brought him no small delight.

However, there is also the following entry in his diary: 'I cannot but mention that the delight I take in the arts is marred for me by the longing for science... for it alone serves the purpose of my life; why don't I quit everything and do only physics?!'

Bidding farewell to Italy, Sergei wrote: 'I came to Italy to pay homage to Galileo's remains. Rest in peace, Dante and Rossini! You did great things, but it was only Galileo who did something really monumental. What may prove to be my last bow to Italy is intended to be the credit I give not to her arts, but to science. Here, at the foot of Galileo's grave I practically swear to devote myself entirely to the worthy cause of science, and if my endeavour is to prove futile, there will at least be the satisfaction that I have made an effort.'

In the days when he was a student, Sergei's ties with

his former schoolteacher Ivan Evseev did not slacken. They often saw each other and even spent their holidays together. With Evseev and his whilom schoolmates Sergei visited Novgorod and Pskov, cruised on the Volga River and paid tribute to the famous places frequented by Pushkin—Mikhailovskoye, Trigorskoye, and Svyatye Gory.

At that time Evseev was elected chairman of a society for the teachers of graphic arts which published its own periodical *Izvestiya*. Evseev was its regular contributor. It was probably Evseev who suggested that Sergei should publish an account of his trip to Italy on its pages.

Vavilov liked this idea and in 1914 as well as in 1916 he wrote two articles based on his travelling notes about the cities of Verona and Arezzo. Their style was exceptionally vivid, and they contained a host of interesting historical data. The readers received the impression that Vavilov was their guide on a fantastically interesting excursion to museums, cathedrals, and other remarkable sites of these renowned cities. The story itself was lavishly illustrated, and when reading the articles it's hard to believe that their author was not a professional art critic but merely an undergraduate studying physics.

When Sergei Vavilov was already President of the USSR Academy of Sciences, he would sometimes enjoy spending long evenings looking through albums containing the reproductions of masterpieces by Leonardo da Vinci or some other Italian artist, which often took upon themselves the role of the sandman of his early childhood days. The affinity with art provided him with the vitality that was so essential to his successful creative activity.

The profound interest in Italian painting made Sergei Vavilov a prominent connoisseur in this particular field. Academician Bentsion Moiseevich Vul said that once, in the days when Vavilov was President of the Academy, he was shown a canvas by some unknown Italian artist that was discovered in the reserve stock of the Hermitage. After scrutinizing the picture Vavilov suggested who the author might be. The experts who appraised this work of art were unanimous in agreement with Vavilov.

What contributed to Vavilov's success when travelling abroad was his perfect command of many languages: English, German, French, Italian, and Polish. As has already been mentioned, the Commercial School did not

provide its pupils with any adequate language training, and it was in good time that Sergei, cognizant of how important foreign languages were for a scientist, had rolled up his sleeves to make up for the time that was lost. He studied on his own and discovered no minor propensity for the acquisition of languages.

Academician Vavilov used to recall: 'Subsequently it took me no pains to spend only a few months to learn Italian; I taught myself to understand it, and to read and even write in that language. I learned Latin and passed the examinations in it. When it was necessary, I could manage to somehow make my way through books written in Dutch or Spanish. On the whole I never found it difficult to acquire at least a passive knowledge of foreign languages. I could read French and German detective novels more speedily than the Russian ones. Without the aid of tutors, and with no sound knowledge of languages, I myself could teach my son Victor to be able to read fluently the books in English, German and French without the use of a dictionary. My method consisted in intensive reading of adventure books, thrillers, and historical novels.'

In 1935, when Vavilov was touring Europe, he made his acquaintance with Vaseo Ronci, Director of the National Optical Institute in Florence. The latter was pleasantly surprised to hear a foreigner speak Italian with such ease. It took him some time to believe that Vavilov owed his perfect command of conversational Italian entirely to a short period of time during which he studied the language in Moscow and his brief stay in Italy prior to the First World War. Ronci wrote: 'It is common knowledge that Slavs are proficient in learning languages, but I didn't know that this kind of mastery could be achieved in so short a period of time.'

Natalya Smirnova, Vavilov's reader, used to recall how, when the woman interpreter doing translation at a meeting where Sergei Vavilov met with Italian students stumbled in her speech, with a cunning smile the Russian physicist started speaking Italian delighting his young listeners.

In his student days Vavilov got infatuated with music. These are his exact words: 'Music can do everything—it can alleviate the wrath, bring joy or tears, or make a person feel happy. How wonderful it is that this kind of art lacks any museum-like qualities. As life itself, music be-

longs to all. And it would not be paltering with the truth to say that I am beginning to understand why mathematicians and physicists love music—it is for its lack of folly that wholly coincides with their own professions'. Vavilov could listen to Bach, Hendel, Beethoven and List for hours on end.

In the spring of 1914 Sergei began taking his final examinations. During all the years as a student he had worked hard and assiduously, therefore the examinations presented for him no particular problem. There was one subject, however—the number theory—that was beyond Sergei and his friend and namesake Sergei Rzhevkin. They spent quite a few days at Sergei's home in Srednyaya Presnya street unenthusiastically studying the subject that they were not fond of. But in the end this examination was also passed.

In May 1914 after passing all the final examinations with excellent results Sergei Vavilov graduated from Moscow University with highest distinction. This diploma along with the research he had conducted on thermal decolorization of dyes, made it possible for him to remain at the Physics Department 'to do his professorship training' (the academic activity that corresponds to a postgraduate course of study today).

After the events of 1911 the university was badly in need of specialists. Sergei's promotion was in the offing and there was nothing to impede his career. However, he demonstratively refused to stay at the University, not wishing to work at the place that had been left in protest by his teachers Lebedev and Lazarev, and where according to his own words, 'police officials have replaced the professors'.

By leaving the University Vavilov found himself obliged to do military service.

ENSIGN VAVILOV

In June 1914, two months before the outbreak of World War I, Sergei was made a conscript. The University diploma allowed him to choose the military unit where he was to serve. The university graduate served as a volunteer and enjoyed the right to have some favourable conditions, e.g. a reduced period of service, to be accommodated on his own outside the barracks, etc.

Vavilov was assigned to the 25th Engineering Battalion of the 6th Engineering Brigade of the Moscow military district. The brigade was stationed in the town of Staritsa of the Tverskaya province. For the summer period it was transferred to the village Lyubutskoye in the same province on the bank of the Oka River at a distance of twelve kilometres from the city of Aleksin. It was also the place where Sergei Rzhevkin's grenadier engineering battalion had been sent.

According to Rzhevkin, the young university graduates were subjected to harsh drills as a result of which their self-esteem was severely trampled on. Those of the intelligentsia that served in the army experienced disrespect and humiliation on the part of the non-commissioned officers with whom the young people were in daily contact.

In spite of the unaccustomed circumstances, which were not very pleasant after a carefree life, the military service in the Lyubutskoye camp was relatively easy, and what was the silver lining for Sergei then was the presence of his university friend Rzhevkin. In their spare time the two Sergeis found great relief in talking about physics. At the end of July they took a longish walk to T. Kravets's country house, who at that time lived in the vicinity of Alexin. A day spent in the company of one of Lebedev's most talented pupils remained in the memory of the two young friends for a long time, and later they would frequently recall this visit. This was the last thing they remembered about the peaceful period. On August 1, 1914, World War I broke out.

The units stationed in the Lyubutskoye camp were prepared for combat. On the very first night after the war was declared they took all their military equipment and started on a thirty-five-kilometre march to Kaluga. This was where Vavilov and Rzhevkin had to part only to see each other again in four years' time when the war was already over.

Vavilov's unit was sent to Poland (near Lyublin). The battalion found itself near the advancing German troops and suffered heavy losses. It was the first time that Sergei was under fire. At first Vavilov was a private, then he became a corporal, and after that, a junior, and, later, senior non-commissioned officer. In 1916 on passing the required tests he was promoted to the rank of ensign of engineering forces. He took part in the military activi-

ties at the western and northwestern fronts, participated in the combat march across Galicia (in Austria), Poland and Lithuania, and many times undertook field-engineering under enemy fire.

Having spent over a year in the field-engineering subunits, Vavilov was transferred to a special army radio battalion. The commanding officers had come to the conclusion that it was more rational to make the physicist do the work for which he had been professionally trained. Those serving in the radio battalion were mostly grenadier guards the greater number of whom consisted of the offsprings of aristocratic families from Russia and the Caucasus. The young people were totally indifferent to military service and were completely incapable of handling radio equipment. Vavilov stood out from all the others because of both his origin and his profound knowledge. It took him little time to put his finger on problems concerning the functioning of the radio stations and presently the ensign Vavilov became a deputy commanding officer of the radio battalion responsible for engineering activities with a field radio station under his control.

During the periods of relative calm Sergei thought of science. At the front the news reached him that he had been awarded a gold medal for his graduation paper. The joyful news, however, was shortly saddened by the information about the tragic death of his younger sister Lidiya.

During the First World War radio communication was only beginning to take its first steps. The army availed itself of spark transmitters that utilize the oscillatory discharge: for this reason the radio subunits were known as spark companies. The radio stations that were most frequently used were those produced by the German firm Siemens (parts of these stations were sent over to Sweden, where they were assembled and then sold to Russia), as well as the field radio stations of the Russian Society of Wireless Telegraphy and Telephony. They were cumbersome constructions, each of which occupied the space provided by five two-wheeled carts.

The independence that Vavilov had gained in the radio battalion proved to be congenial to his scientific research. He elaborated the method for taking bearings of the enemy's radio stations. In those years radio contact was maintained only between large army subunits. Radio

stations were assigned to headquarters and were situated in their immediate proximity, thus their location was highly important for the reconnaissance.

The method worked out by Vavilov was simple and yet reliable; furthermore, it presupposed the use of standard receiving radio stations that the Russian army was equipped with. Several receiving radio stations situated at different fixed points would simultaneously receive the signals that came from the radio station whose location was unknown. By the relative force of the signal received by each of the radio stations and by calculations that were in no way complicated, it was thus made possible to fairly accurately detect the location of the unknown radio station.

Vavilov proved that the use of two receiving radio stations helped to detect the area within which the unknown station was located. In the case of three receiving radio stations it became possible to construct two circles the points of intersection of which indicated the possible places at which the radio station to be discovered was situated. Aware of the actual state of things at the front it thus presented no problem to find its exact position. The use of four receiving radio stations helped to find the enemy's transmitter with complete precision.

Vavilov mentioned the most propitious conditions for the realization of his method, recommended the most appropriate types of radio stations, drew the attention to the importance of utilizing detectors of the same type with identical tuning and pointed out that particular stress should be made on the stability in the functioning of the detectors. He suggested that their sensitivity should be checked daily by measuring the intensity of signals that are sent by one of the receiving radio stations at a particular time.

On the twelfth and the thirteenth of October 1916 by order of the commander of the radio battalion of the special army Sergei Vavilov carried out the experiments to verify his method. In the outskirts of the town of Lutsk-Krasnoye, a receiving radio station was installed that was to register the intensity of the signals sent in particular conditions by the nine transmitting stations situated at different points. These experiments substantiated the tenability of Vavilov's method.

Vavilov described his method of taking a bearing of

radio stations in his paper entitled 'The method of locating a radio station by the intensity of its functioning'. The manuscript dated October 17, 1916, was lost. It was found only in 1952 after the death of the author. The article was published in 1954 almost forty years after it had been written.

In his reminiscences Academician Boris Alekseevich Vvedensky reproduces the story as was told by Vavilov about the final stage of his work on direction finding. Vavilov submitted the report to his commanding officer in which the principle of direction finding was illustrated with the help of a drawing that was meant to clearly show the sum and substance of the method without any superfluous formulae. However, the commanding officer and other army officials demanded that Vavilov make his description 'more impressive'. Vavilov conceded and wrote out the formulae of analytical geometry for corresponding circles and straight lines, determined the points of their intersection, etc. The army authorities were satisfied.

Between July and August of 1917 in war-time conditions Vavilov managed to complete one more paper which he titled 'Frequency of Oscillations of the Loaded Aerial'. In it he deduced the formula that is highly significant for radio engineering. This research was published only in 1919.

In the years of the First World War the young scientist wrote several other papers. Thus, in 1915 Vavilov published the short report 'On one possible deduction from the experiment of Mackelson and others'. Now and then foreign periodicals on radio engineering made their way to the radio battalion. Vavilov read them very attentively. In 1917 he published several papers on radio engineering in a periodical dealing with the latest achievements in radiotelegraphy and electrical engineering.

Vavilov loved Goethe as much as his teacher Lebedev did. At appropriate moments he used to quote the great German poet. Ever since he was a young man *Faust* had always been his desk book. What attracted him in this masterpiece was the philosophy of life and its meaning, the thoughts about science, and the role and function of a scientist, and his social duty. Vavilov read its pages over and over again, always discovering for himself something that was quite new. When leaving for the front he took

a small-size volume of the Leipzig edition of *Faust* printed in Gothic letters. In his spare moments he would read and reread his favourite book making notes in the margin. Soon the number of notes was so great that Vavilov started writing in a special notebook that was the same size as the book. In the spring of 1915, in the Polish city of Kielce he had them bound together with the volume itself.

This book also accompanied Vavilov in the years of the Great Patriotic War. It was then that he wrote the following entry: '1942 (Ioshkar-Ola). War again, and again—*Faust*—with the only difference that I am in the rear and not in the front, and I am 27 years older with the whole of life beyond me.' Vavilov collected different editions of *Faust* and had more than forty of them.

The four years at the front changed Sergei greatly. Youth was over. His character and habits were formed completely. He reached the stage of maturity.

At the end of the war he was taken prisoner by the Germans. The officer who captured him was surprised to hear his captive speak impeccable German. It occurred that the captor was also a physicist and the two men found themselves engaged in a lively conversation. The German was favourably disposed to Vavilov and did not take the trouble to have him guarded in any special way. Sergei escaped and managed to cross the front line to join his own forces.

In February 1918 the four years of his wanderings along the paths of war came to an end, and Vavilov returned to Moscow. He saw his country famished and disrupted. There was every reason to believe that there was no place for a physicist under such circumstances. But it turned out that this assumption was quite wrong—Vavilov's knowledge was most urgently required by his nation.

THE BEGINNING

Vavilov's reunion with his family was a joyful event. Almost at the same time his university friends Rzhevkin and Ilyin also returned from the front. However, neither of the two young men had any relatives in Moscow, and Sergei asked them to stay at his home. Vavilov's mother treated her son's friends as if they were her own children and provided them with individual accommodations and

food. Rzhevkin and Ilyin spent several months with the hospitable Vavilovs and forever retained a feeling of gratitude for the kindness of the hostess. Soon their house was given over to a kindergarten and the family was allotted the first floor of the wing adjoining the main building.

The Soviet Power was in urgent need of specialists. In his talk with Maxim Gorky, Vladimir Ilyich Lenin said, 'Tell the intelligentsia to come and join us. Isn't it your own opinion that its representatives serve the interests of equity? What is the problem, then? They are welcome. It was we who took upon ourselves the arduous task of making the people independent, it was we who told the world the truth about life, and showed all the nations the only road leading to human dignity and away from slavery, poverty and humiliation.' The call did not remain unheeded. Many outstanding scientists and representatives of culture came over to the side of the Soviet Power. One of the first in their ranks was P. Lazarev, an Academician since 1917.

As far back as 1911, after the most prominent professors had left the University, N. Umov came up with an initiative to create a scientific institution that would be independent of the government and function on individual donations. Thus at the end of that year the Moscow Scientific Institute and its Society had been organized. A. Mannuylov, the former rector of the University took on the managerial responsibilities. The scientists N. Umov, P. Lazarev, A. Eikhenvald, G. Wulf, and others became active council members.

At that time it was clear to P. Lebedev and P. Lazarev that the small laboratory in Myortvyi Pereulok could only serve as a temporary haven. Relying entirely on the help from the recently formed Society, they worked out a plan to found the Institute of Physical Studies. After the death of Lebedev, Lazarev submitted the plans to the Council of the Moscow Scientific Institute, which endorsed it in principle. The Institute of Physical Studies was founded on January 1, 1917, five years after Lebedev's death. Lazarev was appointed its Director.

The Institute was situated not far from the centre of Moscow, near Miusskaya Square, in a two-storeyed stone building that had a semi-basement. Some of the rooms in the sem-basement were dark and were used for photometric research and studies on physiological optics, in some of

the rooms a constant temperature was maintained. There were also mechanical and glass-blowing workshops at the Institute. A library with a skylight was on the second floor. It contained only 538 volumes. According to Aleksandr Mints, the future academician, who began his work at the Institute in 1918, the library fit into two bookcases. The X-ray laboratory was next door to the library. At first the Institute had only 163 instruments. This number was soon increased when the instruments from Lebedev's former laboratory were added to the stock.

There were very few staff members at the Institute. It consisted of the director and his three assistants—Nikolai Shchodro, Pavel Pavlov, and Aleksandr Trapeznikov. Academician Vassili Shuleikin recalled that everyone else working at the Institute was a trainee rather than part of the staff, and received no remuneration at all. Lazarev was particularly interested in those who had formerly worked in Myortvyi Pereulok and at Shanyavsky University. They were the true enthusiasts who were always ready to selflessly help the Institute in their spare time.

In 1919 the Institute of Physical Studies came under the authority of the RSFSR Public Health Commissariat and functioned at its X-ray, electromedical and photobiological sections. After that it was renamed the Institute of Biological Physics, and in 1929 it became the Institute of Physics and Biophysics. Having become a state institution enjoying full rights, the Institute was soon transformed into a large scientific centre conducting research in biological physics, photochemistry, molecular physics, acoustics, and optics.

When he returned from the front, Sergei Vavilov got in touch with Lazarev in no time at all. The latter offered him a job at the Institute, with Rzhevkin and Ilyin receiving the same offer. Since 1919 Rzhevkin had been mainly connected with the Military Radio-Engineering Laboratory, and at the Institute he carried out research on a purely voluntary basis. P. Belikov was yet another war veteran who was then working at the Institute.

A. Mints, who had joined the Institute at an earlier date, was considerably younger than those who had been at the front lines, and at first did not have the courage to speak on a par with his experienced colleagues. However, soon he managed to establish friendly relations with them. Those were the years of hunger, and the young people or-

ganized a collective vegetable garden behind the Institute's building where they planted potatoes. Presently Mints went to serve in the Red Army as commander of a radio battery in the First Mounted Army. Thus, he was unable to enjoy the fruits of his own agricultural endeavours since in his absence the harvest was shared by the other physicists. This became a standing joke with the Institute people and Mints did not miss the chance to demand the return of 'the potato debt'.

The Commissariat for Public Health commissioned the Institute to design new X-ray installations for medical purposes and research in physics. It was here that in 1918 the first model X-ray laboratory was created in Russia, and it was precisely where on the 22nd of April 1922 V. I. Lenin was X-rayed before he was to be operated on for the removal of the bullet that remained in his body after the assassination attempt that occurred on August 30, 1918.

At the Institute of Physical Studies Vavilov received his first managerial post of head of the Physical Optics Department. He had held this job for eleven years until 1930. During the years at the Institute, Vavilov completed a number of fundamental investigations on luminescence and physical optics.

There were quite a few difficulties at the outset. There were an insufficient number of instruments, the library was meagre and received no recent foreign periodicals, and it was not infrequent that the power supply was disconnected and the voltage became unstable. Entries of the type 'The decrease in the reading was due to a drop in voltage received from the city's supply line' appeared now and then in Vavilov's laboratory notebook.

What served to promote the research was the help received from Nikolai Semashko, the then Commissar for Public Health, who also devoted much of his time to the improvement of the living conditions of scientists. It was on his initiative that in 1919 the Central Commission concerned with the material welfare of those engaged in research was organized. The research team at the Institute was thus provided with food rations on a par with all the other scientific workers. This was indeed a great help in those very hard years.

Owing to the care that came from N. Semashko the library at the Institute began to grow, and access was

made even to foreign scientific journals. A colloquium started meeting to discuss the results of the work conducted by the members of the Institute. Vadim Levshin recalled that Vavilov often took the floor at such meetings and was *au courant* with all the latest scientific trends. He was very well read in special literature and was doubtlessly the most erudite of the opticians working under Lazarev. All his friends and colleagues were deeply impressed with his knowledge.

The beginning of Vavilov's activity at the Institute coincided with great changes in his private life. His university friend Professor E. Shpolsky used to say that in 1919 Sergei started looking for the accommodations that would suit him. It was the time when the housing problem in Moscow was very acute. Those who had large flats were obliged to share their living space with others. Among them was Victor Vesnin, the architect and one of the three talented brothers who were later called 'the three *bogatyrs* (epic warriors) of Soviet architecture'.

Not wishing to have any undesirable person under his roof, Vesnin had decided to find a neighbour himself and asked Shpolsky, who lived on the same landing with him, to help him in his quests. Shpolsky, aware of Vavilov's plans, recommended him to his neighbour. The Vesnins and their lodger found very much in common and Vavilov moved to the house in Bolshoy Uspensky Pereulok (lane)—now known as Bolshoy Mogiltsevsky Pereulok—in Arbat (the central part of Moscow).

Soon Sergei made friends with the younger sister of Vesnin's wife, Olga Bagrinovsky. The two young people spent most of their spare time together and on the twenty-fifth of June 1920 they got married. At that time Vavilov was twenty-nine and his wife, Olga was three years his junior. The wedding was held near Nizhni Novgorod in the suburban district of Rastyapino (now the town called Dzerzhinsk) in the house of Vesnin, who at that time was engaged in the construction of a chemical plant. Since that day Olga Vavilova remained with her husband 'for better or for worse' for the thirty years of their married life.

Olga Bagrinovsky had been brought up in a family that belonged to the Russian intelligentsia. Her father, a barrister by profession, worked in partnership with the famous lawyer Fyodr Plevako; her brother was a professor

of the Moscow Conservatoire, one of her two uncles, Mikhail Khvostov, was an historian, and the other, Vladimir Khvostov, was a lawyer. Both were professors at the university in Kazan. Her aunt Olga Alekseeva was an actress at the Moscow Art Theatre and was the wife of Boris Alekseev, also an actor and the brother of the eminent producer Konstantin Sergeevich Stanislavsky.

Since the days of their childhood the Bagrinovsky sisters had been surrounded by music, literature, and theatre. It was Olga's dream to become a singer. Shortly after the outbreak of the First World War she entered the Moscow Conservatoire, but had to leave it in 1916, when she volunteered to go to the front. There she spent two years working in a unit that helped the children who had lost their parents.

When Olga Mikhailovna came back home, she stayed with her elder unmarried sister, who had two small rooms in a densely inhabited flat in the Eropkinsky Pereulok in Prechistenka (now called Kropotkinskaya Street). When her sister married Vesnin and moved to her husband's flat, the Vavilovs were left the two rooms for themselves. This marked the beginning of the two young people's life, replete with happiness and hardships. E. Shpolsky often said that one could hardly imagine a better couple than Sergei and Olga.

Rzhevkin recalls that all of Vavilov's friends and colleagues made friends with his wife immediately. She was beyond any doubt a woman of great charm and intellect. It soon became a tradition for the families of S. I. Vavilov, S. N. Rzhevkin, P. N. Belikov, S. V. Kravkov, E. V. Shpolsky, and others to see the New Year's in together as well as to spend St. Tatyana's Day (Tatyana being the University's patron saint) and other holidays together.

The year 1921 brought joyful tidings to the Vavilovs. Their son Viktor was born. Today Viktor Vavilov is a prominent specialist in the field of solid-state physics and works at the Lebedev Physical Institute of the USSR Academy of Sciences where he is in charge of the section of radiation physics of semiconductors at the semiconductor laboratory. He is a professor of the faculty of physics at Moscow State University where he heads the department of semiconductors, V.S. Vavilov is a USSR State Prize winner.

It is the twenties of the present century... The economy is disrupted, the harvest is bad, there is no fuel to heat the rooms, and there are many daily cares connected with the newborn child. Even for little Viktor's pram they had to pay 15 billion roubles. All this could not but impede the progress of work. In 1921 Nikolai Vavilov was sent on a mission to the USA to discuss the purchase of seeds for Russia. Denying himself the barest necessities, he sent food parcels to Moscow trying to help his relatives in those very hard times. Those parcels were a great relief to Sergei Vavilov's family.

After Olga recovered from childbirth she made an effort to resume her vocal training. She began to take lessons with Maria Vladimirova, the sister of Valeria Barsova, the world-famous Russian soprano (1892-1967). However, the effort was too great for her and she had to abandon her studies. And yet, irrespective of all the difficulties, the young woman remained an optimist to the end.

The beginning of Vavilov's scientific activity coincided with a highly significant event in the field of physics. It was the emergence of the works of the German physicist Max Planck and the Dutch physicist Niels Bohr, their achievements made it essential to reconsider the generally accepted viewpoint as regards the phenomena of light as purely wave electromagnetic processes. These works gave rise to the foundation of new, quantum theory pertaining to the nature of light. It was made evident that outside the quantum theory it was impossible to understand a whole series of effects which came into observation in the process involving the interaction of light and matter. At the same time, a large number of highly important optical phenomena, such as interference, diffraction in the process involving the interaction of light and matter. At the same time, a large number of highly important optical phenomena, such as interference, diffraction and the polarization of light found tenable interpretations in terms of the wave theory. Data pertinent to the nature of the phenomena of light were extremely contradictory. The quantum concepts were only beginning to gain their right to existence and called for further substantiating evidence that could be provided by more subtle experiments... Meanwhile, the very word 'quantum' was written in quotation marks by those working with Lazarev.

Sergei Vavilov took great interest in the nature of light phenomena and had been recurring to the subject of its analysis over many years. The cycle of his works in this field began with the investigation of the absorption and emission processes of light by elementary molecular systems. It is to him that we owe the discovery of quantum properties of a large number of phenomena that had previously been regarded as having a typically wave character and contrary to the concepts advanced by the quantum theory. Vavilov made it abundantly clear that between the wave and quantum properties of light there exists the closest possible link.

In 1920 at the Institute of Physical Studies, Vavilov initiated a series of works devoted to the clarification of the limits to which the basic law of the absorption of light could be applied when it passes through a substance. The said law was formulated by Pierre Bouguer as far back as 1729 and in accordance with it there exists a proportional (linear) dependence between the quantity of light that has been absorbed in the layer of a substance that absorbs it and the intensity of the incident light falling upon it. As is actually the case, the light passing through the layer of some substance is partially absorbed and becomes a certain number of times weaker. When the intensity of the incident light is either increased or decreased, it is quite natural for the light on coming out of the substance to either gain or lose in its intensity. However, the amount of light absorbed by the substance as was stated by Bouguer is expected to remain constant in both cases. Prior to Vavilov's research the tenability of this law had been verified within a narrow range of intensities of the absorbed light flux. In Vavilov's opinion the verification of its applicability to a considerably wider range of intensities was of principal value, since it allowed to experimentally substantiate the quantum nature of the phenomena of light.

The idea that lay behind his experiments consisted in the following. If light is actually radiated in quanta (portions), which are usually referred to as photons, then their number at each particular moment will not be the same, but is bound to fluctuate around an average value. This gives us the right to infer that the quantity of absorbed light will be different for each particular interval of time.

In normal conditions the light intensity is so great and the quantum fluctuations are so insignificant that they may escape the researcher's notice. Things were expected to be quite different when the experiment was to deal with very weak light fluxes. In this case, according to Vavilov, there was a certain hope that irregular variations in the absorbing property of a substance would be discovered and this would substantiate the quantum nature of light.

Possibly, the quantum nature of light could be further corroborated by investigations involving the light fluxes of ultimately high intensity, i.e. when the molecules of a substance, in absorbing the quanta of the incident light, are transferred into an excited state of greater energy. With an increase in the intensity of incident light the number of molecules that come into a state of excitation grows, which results in that the absorption of light becomes weaker. In situations like these Bouguer's law ceases to remain tenable.

It was Vavilov's aim to prove the validity of the quantum nature of light by means of unambiguous experimental data. He had designed two set-ups one of which measured the absorption when the incident light was of either low or medium intensity, while the other was used when the light was very bright. What served as the objects of analysis included Rhodamine- and magenta red-dyed colloidal films as well as aqueous solutions of these dyes. In summing up the results of a series of the experiments, Vavilov came to the conclusion that Bouguer's law was faultless in those cases when the intensity of the light flux varied over a 10^{15} order of magnitude.

Having obtained this result, Vavilov approached the study pertinent to the absorption of light fluxes of very low intensity. What served him as a sensitive receiver was the human eye, the fact that it has a markedly expressed limit (energy threshold) for the perception of light having been the decisive factor in making the choice. This work was methodologically most important. It gave rise to the study of quantum fluctuations of light and brought back the method of photometry which had been employed by physicists and astronomers over two hundred years ago but which was now in abeyance. By determining the extent to which the light flux should be attenuated so as to reach the threshold sensitivity of the

observer's eye (the prerequisite being that the person had spent a fair amount of time in darkness), the researcher establishes the intensity of the given flux. In this case the human eye functions as an infallible instrument. As early as 1916 Lazarev proved that the threshold of visual stimulation of green incident light was equal to the energy of 10^{-9}-10^{-10} erg per second.

To take the measurements Vavilov designed a special experimental set-up. What served as the source of light in it was the fluorescence of an aqueous solution of a dye known as Rhodamine 5 G, which is characterized by a maximum intensity of radiation in the green part of the spectrum. The luminescence was excited with the help of a 100-W incandescent lamp, whose radiation intensity was regulated by a rheostat capable of varying the intensity of fluorescence to 10,000 times of its value.

Before the observations began the experimenter had to become adapted, i.e. to remain in a completely dark room for some twenty or thirty minutes, and only after that start his work. On account of the fact that the measurements were conducted at the sensitivity threshold of the human eye, each test was repeated thirty to forty times. In order that the influence of any specific properties of the eye of a particular person be excluded, Vavilov asked many of his Institute colleagues to help him by taking the part of observers.

As a result of elaborate and most exhausting measurements Vavilov managed to discover that Bouguer's law was also rigidly obeyed in the region of ultimately low intensity of the incident light. Vavilov's experiments proved the tenability of Bouguer's law within a wide range of light intensity (the researcher had subjected it to variations amounting to 10^{19}, or billions of billions of orders of magnitude).

In 1920 the First Congress of the Russian Association of Physicists was held. Vavilov's report was 'on the limits of the basic law of absorption'. In it he generalized the results of the work that had been carried out. The inadequate development of the quantum theory did not allow him to arrive at the correct conclusion. Interpreting the results of the experiment, he wrote, 'The validity of Bouguer's law within this interval contradicts the hypothesis of "light quanta", and any attempts to apply it more or less systematically have to be dispensed with.'

It took years of strenuous work to produce a feasible explanation of what had been achieved as a result of the experiments. Their interpretation in terms of the quantum theory was suggested by Vavilov in his monograph *The Microstructure of Light.*

Under ultimately low intensities of the incident light flux the absence of light fluctuations finds its explanation in the physiological properties of the eye, which retains visual perception within the period of 0.1 part of a second. This leads to the averaging of the activity of light quanta with the span of time that is being studied, and the light fluctuations become unnoticeable to the one engaged in the experiment.

The absence of any variations when the intensities of the incident light flux are high is conditioned by the fact that the average duration of the excited state of the molecules of the dyes that were investigated by Vavilov, comprises only billionths of a second (approximately 10^{-9}). When this time expires, the molecules emitting electromagnetic radiation change to ground state again. In order that a considerable amount of molecules could be sustained in this condition, there should exist light fluxes of gigantic intensity. It goes without saying that the physics laboratories of the twenties had but modest facilities and could not promote any tangible change in the absorption value of substances under analysis.

Further quests were bringing ever new results substantiating the quantum concepts of the nature of light. This made Vavilov return to his previous tests. In 1925 together with Levshin he again took up the experimental verification of Bouguer's law. In a year's time the authors published the results of their research in the article 'The correlation between fluorescence and phosphorescence in solid and liquid media'. In its essence the work was devoted to problems that were not related to the quantum theory of light, though its concluding section proved to be immediately connected with it. It was subtitled 'The possibility of attenuating the absorption of fluorescent and phosphorescent bodies when illuminated by the light of a spark'. In the given part of their paper Vavilov and Levshin expounded the sum and substance of the outstanding discovery, which gave rise to a new branch of science now known as non-linear optics.

The calculations that were made for the most power-

ful source of light that the researchers had at their disposal, viz. the condensed electric spark, revealed that there was some hope of discovering marked deviations from Bouguer's law only in the case of those substances the molecules of which remain in the excited state for no less than 10^{-4} s.

Indeed, the experiments with the aqueous solutions containing fluorescein (whose molecules remain in an excited state for 10^{-9} s) had confirmed Vavilov's previous results; Bouguer's law was found accurate to 0.3%. After that Vavilov and Levshin decided to use uranium glass as an object in their analysis. The average duration of its molecules in the excited state was about 5×10^{-4} s, or approximately 100 000 times greater than that of the molecules of fluorescein.

The tests proved to be highly successful. It was the first time that deviations from Bouguer's law had been discovered experimentally: under the activity of powerful radiation produced by a condensed electric spark there occurred a drop in the absorption coefficient of uranium glass. The effect, however, was not great, viz. the variation of absorption comprised only about 1.5 per cent.

It was by no means the fortuitous success of the researchers who happened to come across an effect that was worth their notice. It was a discovery that had been foreseen by Vavilov, and he had been paving the path to it most perseveringly for many years. The idea he expressed in his earlier works was fully confirmed when the object of research was well chosen. In a later period Vavilov showed that when light is propagated through a certain medium deviations from the linearity of absorption conditioned by the quantum nature of light and the substance itself become apparent.

It turned out that absorption can depend even on incident light of not great intensity. Thus, marked deviations from absorption linearity can be found with a large number of dyes placed in vitreous media. The duration within which the molecules of these dyes remain in the excited state is equal to one second or more. This becomes particularly evident with complex luminescing inorganic substances, such as phosphor-crystals, which are characterized by a highly prolonged period of afterglow.

The effect discovered by Vavilov and Levshin was the first step in the creation of a new, extremely important,

and nowadays rapidly growing science known as nonlinear optics. At present the Vavilov-Levshin effect is widely employed for the manufacture of optical shutters that are used for the generation of gigantic pulses in solid-state optical quantum generators (lasers). An optical shutter is a cuvette containing a liquid that possesses the property of becoming transparent under the influence of a light beam of particular power. The shutter operates only after the crystal has reached a highly excited state, and the latter that generates an exceptionally powerful laser beam. In 1928 the Sixth Congress of Russian Physicists was held in Moscow. In his reminiscences Moisei Markov wrote that among those giving reports was Sergei Vavilov, 'he was as lissom as would become a young man and extremely swarthy'. He spoke of the attempt to determine the limits to which the well-known principle of superposition could be applied. In accordance with this principle there should be no interaction between two intersecting light beams. This principle had been known long before and had been actively discussed even by Christian Huygens, Isaac Newton, and Mikhail Vassilyevich Lomonosov. It was fairly well explained by the wave theory of light and no one had ever noticed its distortions.

However, the existence of this principle seemed to contradict Newton's corpuscular theory of light phenomena. Its opponents pointed out that light corpuscles would necessarily collide, which would inevitably lead to the violation of the superposition principle. Lomonosov suggested that one should look for the possible interpretation of this phenomenon in the excessive smallness of light corpuscles.

Vavilov wrote, 'Nowadays optics is found to be in the stage of the theoretical synthesis of wave and corpuscular views, and the problem referring to how far superposition is valid is again becoming somewhat moot.' By taking into consideration the fact that light beams consist of individual quanta, Vavilov made the following assumption: If the density of light fluxes were markedly increased and made to intersect one another, then some of the light quanta could find themselves in collision with each other. This should bring about the diffusion of light, which fact would precisely serve as experimental proof that the principle of superposition was violated.

To carry out his experiments, Vavilov designed a set-

up in which a powerful condensed electric spark was used as the source of a high-density light flux. The light emitted by it was focussed inside a vessel from which the air had been evacuated. Vavilov estimated that in the installation he had at his disposal the instantaneous values of radiant energy density could be so great that they would exceed its corresponding values near the Sun's surface. However, the experiments did not bring the desired results. The diffusion of light remained undiscovered. The scientist came to the conclusion that there was very little probability of the collision of photons.

To determine the upper feasibility limit of the principle of superposition, Vavilov availed himself of the data on astronomical phenomena. He wrote that near the Sun's surface incoherent beams were known to intersect, i.e. those that are emitted from its different parts (in contradistinction to the ones mentioned, the sources of light oscillating in identical phases, or with a constant phase difference, are called coherent; and it is only the coherent light beams that are capable of interfering with each other), and these intersections occur when the radiation densities are very high and the amount of radiation is great. Furthermore, the results for the terrestrial observer are summed up. At the time of total solar eclipses, when the direct rays of the Sun are hindered and the background becomes excessively dark, the experimenter on Earth finds himself in highly advantageous circumstances for conducting observations, with the Sun itself serving as an object for the determination of the feasibility limits of the principle of superposition.

As is known the light of the solar corona near the Sun's surface is diffused. This phenomenon is interpreted as a result of the diffusion of solar rays by the electrons, atoms, and molecules of a rarefied gas. Vavilov carried out the precisely idealized calculation. He assumed that all the diffused light under observation was brought about by the collision of light quanta, or photons. It occurred that even in this case the radius of the range within which the photons were functioning was excessively small, considerably less than 10^{-20} centimetre, i.e. 10 million times smaller than the radius of any known elementary particle. If, however, we took into account the diffusion of light by electrons, atoms, and molecules, this value would prove to be even much lower.

The calculation revealed the futility of any attempts to discover the diffusion of light by experiments carried out in ordinary laboratory conditions. Even now, when the enormous capacities of light beams radiated by lasers are at our disposal, we still cannot expect any positive results in experiments of this kind. Vavilov demonstrated that the principle of superposition of incoherent light beams is executable with a great degree of accuracy within markedly wide limits. In his own words this principle—at least for visible light—may well be regarded as one of the most irrefutable tenets of optical studies.

These experiments were carried out in very difficult conditions. At that time the Institute had neither laboratory assistants nor anyone to clean the rooms, and the researchers were obliged to keep the rooms in order themselves. Levshin recalled that in 1924, in connection with the celebration of the bicentenary of the Academy of Sciences, a great number of guests from other countries were expected to come to the Soviet Union. To prepare the laboratory for this event, Vavilov and Levshin worked hard cleaning the windows, scrubbing the floors and setting everything in order on the laboratory benches. Max Planck, who headed the group of German physicists visiting the laboratory, was pleasantly surprised by how perfect the scientific facilities of his Moscow colleagues were

THE MAN WHO SAW LIGHT QUANTA

Failures did not stop Vavilov from becoming ever more convinced that the quantum nature of light was a scientifically valid concept. At last he decided to design an experimental method that would allow one to observe the behaviour of individual photons. To conduct such subtle tests, it was necessary to work with light fluxes of extremely low intensity, and, consequently also with highly sensitive light collectors, capable of registering any minute number of light quanta. In 1929 at the Institute of Physics and Biophysics, Sergei Vavilov and Vera Fedorova accomplished the first promising experiments. However, they were not confident enough that the discovered small effect was not brought about by, to quote Vavilov, purely psychophysiological factors.

In 1932 the work of the German scientists R. Barnes

and M. Cherny was published. The authors had made an attempt to discover the quantum fluctuations of light (accidental deviations of the number of emitted light quanta from the average number of quanta in the light flux) with the help of the human eye adapted to darkness. Vavilov noticed many problematic points in the research. He carried out a series of classical experiments on the quantum fluctuations of light. The investigations were conducted together with Evgeni Mikhailovich Brumberg, Zinovi Mikhailovich Sverdlov, Tatyana Vladimirovna Timofeeva, and K. L. Panshin. They were conducted at the State Optics Institute over a period of ten years and were completed in 1942.

The idea underlying the experiments consisted in the following: with time basic optical characteristics of extremely weak light fluxes (illuminance, luminous intensity, etc.) should vary randomly. Fluctuations of this kind are of quantum nature. This is due to the fact that each molecule of a radiating substance glows spontaneously, and irrespective of any other molecules. This should lead to quantum temporary fluctuations in the basic characteristics of the glow. These fluctuations are independent of temperature and are manifested under any considerable drop in the intensity of the light flux under investigation, when a very small number of light quanta are incident on a surface per unit time.

Vavilov liked the idea of using the eye adapted to darkness as a receiver of light collector. As a matter of fact as far back as 1920 he himself had implemented this idea in his experimental studies connected with the verification of Bouguer's law for light fluxes of extremely low intensity. The human eye is a complicated light collector. Its light-sensitive nerve endings include small rods and cones. The former, situated in the peripheral part of the retina, are characterized by a high degree of sensitivity, but do not react to differences in colour. The latter are found in the basic, or central part of the retina. Though less sensitive, they help to distinguish the colours and minute details of the object under observation. Owing to this, human beings possess two types of vision: daylight (photopic) vision, which is also called basic and is connected with stimulation of the cone, and scotopic, or peripheral, vision (associated with stimulation of the small rods).

In normal conditions the two types of vision function simultaneously. However, under low illumination the sensation of sight is at the expense of scotopic vision. During the transition from very high to very low light intensities the eye at first does not see anything at all. However, after a certain period of time (30 or 40 minutes) it begins to distinguish objects, this is when scotopic vision starts functioning. This kind of process is usually referred to as dark adaptation. The sensitivity of the completely adapted eye is very high. This was precisely what gave R. Barnes and M. Cherny the idea of utilizing the eye in their experiments. But the results of these experiments proved to be erroneous. According to Vavilov they had been carried out in such a way that made it totally impossible to control the numerous marked physiological fluctuations, which are well known to physiologists and psychologists and are much more prominent and contrastive than the expected quantum fluctuations.

Vavilov gave a detailed analysis of the errors involved in the research, evaluated the investigation objective, and decided to apply them to his own experiments. What came in handy was the experience he had gained when working with low-intensity light fluxes to verify the validity of Bouguer's law. As in the previous case, the scientist made use of the eye's high sensitivity, which in his own words is the most subtle, universal and powerful of the sense organs, capable of detecting light within a period of about 0.1 s when only several tens of quanta enter it. No less important is another property of the eye: the threshold of visual sensation. If the number of quanta that fall upon the retina is less than that corresponding to this particular threshold, then the eye will not perceive the light flash. Vavilov advanced a method of investigating the quantum fluctuations of light, which was based precisely on this visual property.

In creating an extremely small light flux near the threshold of visual sensation one would expect a fluctuation in the intensity of the flux due to the quantum nature of light. The fluctuations should occur in compliance with the law of statistical physics and be registered by the eye.

If the number of quanta that reach the retina exceed the threshold of visual sensation, the observer is bound to perceive the light flash. At the next moment, as a re-

sult of the fluctuation, the number of quanta may be below the threshold, and the light signal will escape the eye. By knowing the number of transmitted signals and registered flashes, it is possible to determine the number of light pulses that contained an amount of quanta insufficient for visual perception.

Vavilov came to the conclusion that to successfully carry out the experiments the light flashes had to be of short duration, the dimensions of the image on the retina had to be small and the image had to be rigidly fixed in its position. The fact is that the quantum fluctuations in a continuous light flux acquire an average value, and they fail to be detected since visual perception is retained by the eye over a relatively long span of time. It should also be mentioned that different parts of the retina have different degrees of sensitivity, which can cause considerable fluctuations in visual perception that has nothing in common with the fluctuations of the number of quanta that strike the eye.

Hence, what is called for is the clear-cut fixation of a small section of the retina with which the light flux comes into contact. When this condition is strictly observed, and the intensity of the light flux is near the threshold of visual sensation, then the quantum fluctuations should be observable unless the theory of the quantum nature of light is erroneous. It was with precisely these requirements taken into account that Vavilov had designed his apparatus.

The experiments on the quantum fluctuations of light were carried out with great precision. Over a period of ten years, Vavilov himself and more than ten observers took hundreds of series of measurements. The enormous amount of experimental material was processed using methods based on the probability theory and the results revealed that light fluctuations have a statistical character and are, consequently, brought about by random variations in the number of photons approaching a certain threshold value determined by the threshold of visual perception. Thus the hunt for photons had been crowned with success. The quantum nature of light had received coherent experimental substantiation, and Sergei Vavilov had become the first person 'to see' light quanta.

The investigations on the quantum fluctuations of light also led Vavilov to important conclusions in the

field of physiological optics. Throughout his life, he attributed great significance to this particular branch of science; and on his own initiative All-Union conferences on physiological optics, uniting Soviet specialists working in this domain, began convening in 1934.

At the Second All-Union Conference, which was held in Moscow in 1946, its chairman Sergei Vavilov stated that scientific studies of the eye comprised the main part of optics, and hence it would not be an exaggeration to state that what should constitute the theoretical basis of optics, alongside the physics of light, was primarily the physiological aspect of optical studies. Particular attention should be focused on the latter and the successful solution of problems in this field calls for the efforts of not only physiologists and ophthalmologists but also physicists.

In 1940, on Vavilov's suggestion a special periodical entitled *Problems in Physiological Optics* began to appear as a collection of papers. For many years Vavilov remained a member of its editorial board. In 1944 he took an active part in organizing a commission for the coordination of research in the field of physiological optics in the division of biological studies of the USSR Academy of Sciences.

The investigations on the quantum fluctuations of light proved to be especially significant for understanding the eye's physiology. Vavilov had discovered a new and extremely subtle means of investigating the inner parts of the eye, which made it possible to determine the eye's sensitivity threshold for different wavelengths of incident light. Thus, it was established that for green light with a wavelength between 500 and 550 nanometres (1 nanometre being equal to 10^{-9} metre) the number of light quanta that correspond to the threshold of visual perception vary among different people within the range of 8 and 47 (20 on the average), while the number of light quanta that come into contact with the retina varies from 108 to 335. These figures reveal that a considerable number of incident quanta are absorbed by the eye's crystalline lens and do not reach the retina.

Vavilov's method opened up the possibility of investigating the transparency of the eye's media to light beams of different wavelengths. Thus he established quite a new characteristic property of the eye. He proved that

besides the known maximum of sensitivity in the visible region of the spectrum (approximately 500 nanometres), there is also a second maximum of sensitivity, which is located in the near ultraviolet region (about 380 nanometres). The low sensitivity of the eye in this part of the spectrum is caused by the fact that the crystalline lens functions as a light filter that markedly attenuates the short-wave part of the spectrum of radiation and protects the retina from its hazardous effect. The existence of the eye's second maximum of sensitivity was also confirmed by further experiments.

Vavilov's work on the quantum fluctuations of light attracted the attention of many other scientists. Academician Dmitri Rozhdestvensky said that the research was of fundamental significance, and that he valued it highly. Vavilov's experiments stimulated a whole series of very important scientific investigations. Thus, in 1943 Academician Aleksandr Lebedev proposed that when weak light fluxes are registered the resolving power of the eye and other visual systems (the ability to discern minute details of the object under observation) should be restricted by their quantum fluctuations: the fecundity of this idea was substantiated by the works of the Soviet physicists Andrei Luizov and Sergei Maizel.

Vavilov's research attracted the enormous interest of foreign scientists as well, serving as the starting point for a series of investigations in countries outside the USSR. Thus, in 1941 the American physiologists S. Hecht, S. Shler, and M. Pirren carried out experiments employing Vavilov's method. However, at first they made no reference to Vavilov, and later they deliberately distorted the meaning of his experiments. In the monograph *The Microstructure of Light* Vavilov revealed that the research conducted by the American authors was groundless. Their research proved to be no more than a repetition of the results that Sergei Vavilov had long published, their version leaving much to be desired.

In 1944 a paper appeared by the Dutch physicist Albert Jacob Joseph Van der Welden, who, twelve years after Vavilov, 'discovered' the method of quantum fluctuations. However, it occurred that the results obtained by Van der Welden and later M. Bowman were not in agreement with the data of either Vavilov or Hecht.

After the quantum fluctuations of light were estab-

lished Vavilov attempted to discover quantum properties in light phenomena considered to be of typically wave nature. First and foremost he studied quantum fluctuations in coherent light beams. In 1934, together with E. Brumberg, he investigated the interference of light in the case of the minimal intensities of interfering light beams.

The phenomena of interference had usually been studied in conjunction with the interaction of coherent light fluxes, whose intensity was sufficiently high. In such cases one could witness a stable interference pattern. The alternation of light and dark bands in it was determined by the relationship between the phases of interfering light beams, which was dependent on the point of observation.

Things are quite different when the interfering beams of light manifest their quantum properties: the light quanta do not reach the dark-band region of the interference pattern. At minimal intensities of the interfering fluxes of light, the light bands are characterized by various intensities at different moments. The appearance of fluctuations in the intensity of the light bands is brought about by the fluctuations in the number of quanta in the interfering beams.

Vavilov and Brumberg were able to discover these effects. The dark bands of the interference pattern did not undergo any changes, while at the same time in the light bands there was a clear-cut manifestation of irregular fluctuations in intensity. Thus, it was proved that quantum properties could be found even in typically wave processes. The integrity of wave and quantum properties of light (the so-called wave-particle duality) was most convincingly illustrated.

Vavilov conducted yet another experiment on the relative fluctuations in coherent light beams. He directed a beam of ordinary green light at Fresnel's biprism—an optical device, which had in its time been proposed by the French physicist Augustin Jean Fresnel, and consisted of two narrow angle prisms placed base to base. Fresnel's biprism is used for obtaining coherent beams of light in experiments on interference.

In Vavilov's experiments the refracting edge of the biprism was placed horizontally. Two symmetrically arranged coherent green spots came into the field of vision.

Vavilov wrote that when threshold power was reached the two spots fluctuated relative to each other and were very seldom seen at one and the same time. The phenomenon of independent relative vibrations of coherent beams could have catastrophic significance for the wave theory if an attempt were also made to defend it in this case.

Vavilov also achieved similar results in his experiments with the Wollaston polarizing prism proposed by the English scientist William Hyde Wollaston. It is a double-image prism cut from a rhomb of calcite which separates the ordinary beam of light into two linearly polarized beams in mutually perpendicular planes. These beams leave the prism at the same angle as regards the direction of the ordinary light beams. A green ordinary beam of light was passed through the prism. Upon leaving, two linearly polarized light beams in the mutually perpendicular planes emerged. They produced two green spots, which fluctuated independently of each other.

Similar experiments could also have revealed quantum phenomena in another typically wave process—the diffraction of light. These phenomena are observed when light passed around the edges of opaque or transparent bodies, or through narrow slits, resulting in distortion of the rectilinearity of light propagation and observed deviations from the laws of geometrical optics become apparent.

However, in Vavilov's opinion, there was no need to discover quantum phenomena in diffraction since they resulted from the fluctuation principle that had been established, experimentally verified by him and given the following definition: 'Provided the power is sufficiently low, every beam of light that is isolated in one way or another manifests fluctuations of intensity that occur absolutely independently and irrespective of those in any other beam.'

Vavilov's research on the quantum fluctuations of light, which was accomplished in the thirties, serves as a remarkable example of their author's perceptive, elaborate and highly skilled approach to experimentation. At that time there were no instruments whose sensitivity could supersede the human eye, such as the present-day photoelectronic multipliers, which are known to be much more sensitive light detectors over the whole range of optical frequencies. (With the help of such instruments

quantum fluctuations of light lend themselves to observation most readily.) However, the regularities discovered by Vavilov have by no means fallen into abeyance. They continue to be substantiated even when the up-to-date equipment is employed. A case in point is the research conducted by Professor Sergei Fyodorovich Rodionov at the end of the fifties which extended these regularities over the ultraviolet and X-ray spectra.

Vavilov's research on the quantum fluctuations of light has gained world-wide renown. In 1943, for this work and for a series of investigations on molecular luminescence, Sergei Vavilov was awarded the State Prize of the USSR.

THE COLD LIGHT

In spite of the fact that Vavilov's research on light phenomena is highly significant, his main scientific merits nevertheless refer to a different branch of physical optics—the one dealing with the study of luminescence—which concerned him for the greater part of his life. The reason why the scientist had focused his attention on luminescence consisted primarily in that the quantum properties of light were more clearly manifested in this phenomenon.

Luminescence is one of the types of radiation of a substance. It represents the emission of light by atoms, molecules, ions and other more intricate complexes of elementary particles that emerge as a result of electronic transitions within these particles when they decay to the ground state from the excited state. Luminescence is in no way connected with the incandescence of radiating bodies, for which reason it is often referred to as cold light.

Since time immemorial luminescence has attracted the attention of many a scientist. It did not even escape the notice of the ancient Greek philosopher Aristotle. The first attempts to investigate this phenomenon may well be referred to the beginning of the seventeenth century. Later its study was undertaken by such luminaries of science as Galileo, Robert Boyle, Sir Isaac Newton, Leonard Euler, Ruggerio Giuseppe Boscovich, and other outstanding scientists. The first systematic studies in the field of luminescence were realized in the middle of

the last century by the British scientist Sir George Gabriel Stokes and the French physicist Alexandre Edmond Becquerel. A considerable contribution to the study of luminescence was also made by the Russian Academician Vassili Vladimirovich Petrov. However, all that had been done by these scientists had no more than a random character.

It was only at the beginning of the twentieth century that the study of luminescence had begun to acquire the status of an independent branch of science. In explaining the situation that had arisen Vavilov wrote: 'What lies at the bottom of this is that the comprehension of luminescence, though no more than in outline, has become possible only since the quantum properties of light and matter were discovered (the beginning of the 20th century). On the other hand, important technological applications of luminescence could be effectuated only on the basis of new physical and technological results in the other fields of science... In brief, the development of luminescence was hampered by the absence of a tenable theoretical foundation and technological applications on a large scale.'

Having once in the twenties taken great interest in the phenomena of luminescence, Sergei Vavilov devoted thirty years of his life to their study and forever bound his name with this branch of science. In his investigations on luminescence he established some highly significant regularities pertaining to this particular kind of glow and had actually laid foundations in the scientific study of luminescence. In his research he first decided to focus attention on dye solutions and study the optical properties of their molecules. Their total energy, as is the case with the energy of other molecules, is known to be sum of the energy of electrons, the energy of the vibrations of the individual parts of molecules, and their rotation as a whole. Accordingly, we distinguish between electronic, vibration and rotation spectra of molecules.

In 1922 Vavilov published the paper *The nature of wide absorption bands in the visible spectrum*, in which he tried to clarify the nature of electronic absorption bands of the dye molecules, which are located in the visible part of the spectrum. He established that the electronic absorption bands of various dyes were characterized by one and the same form (distribution of the intensities

of absorbed energy over the the frequencies or wavelengths). As is actually the case, if these bands were aligned as a result of their displacement along the wavelength scale, they would practically coincide with each other. Some time later Vavilov came to the conclusion that the universal character of the visible electronic absorption bands of the dyes was not due to individual properties of their molecules but resulted from the continuous interaction between their vibration and electronic states.

The data obtained had a marked impact on research aimed at determining the origin of electronic absorption bands and the radiation of polyatomic molecules, and in particular on the fundamental studies undertaken by Academician Boris Stepanov of the Byelorussian SSR Academy of Sciences and those by Professor Bertold Neporent.

Investigating the nature of photochemical reactions, Academician P. Lazarev established that the ratio of the quantity of the substance decomposed under the effect of incident light to the light energy absorbed during this process did not depend on the wavelength of incident light and remained constant within the limits of a single absorption band. This conclusion contradicted Einstein's law of photochemical activity according to which, given an adequate amount of light quanta, which tends to increase with the wavelength decrease, a proportional relationship between the photochemical decomposition of a substance and the wavelength of incident light should exist.

Vavilov became interested in Lazarev's results and began to study the efficiency of the transformation of the exciting light of different wavelengths into the luminescence of dye solutions. In his first publication on luminescence which was entitled 'The dependence of the intensity of dye fluorescence on the wavelength of exciting light', Vavilov introduced the concept of specific luminescence: the ratio between the amount of luminescence emitted and the amount of energy of the absorbed exciting light that induces the luminescence.

Specific luminescence can be defined as a kind of coefficient of efficiency: it shows the extent to which the transformation of exciting light into luminescence takes place in the substance under investigation. In later years this value was called the luminescence efficiency. In addi-

tion to the term 'luminescence efficiency'one can also often hear the concept 'the quantum efficiency of luminescence', which is taken to be the ratio between the number of luminescence quanta radiated by a substance and the number of quanta absorbed from the exciting light.

At the third All-Union Congress devoted to the problems of luminescence which was held in Moscow in 1951 already after Vavilov's death Levshin stated: 'In his remarkable research on luminescence efficiency Sergei Vavilov used to designate this phenomenon by various Latin and Greek letters. I think that we shall be fully justified, if in his honour, we shall designate the luminescence efficiency by the Russian letter 'B'...' (the initial letter of the name 'Vavilov' in Russian). His proposal was accepted, and thus the Russian letter 'B' came to be used by the scientists.

It was Vavilov's idea to excite the luminescence of dyes with light of different wavelengths. However, in those years science did not have at its disposal the required spectral instrument—the monochromator. Hence he was compelled to make use of light filters, which allowed the passage of wide regions of the spectrum. Gelatine sheets that had been coloured with various dyes were used for this purpose. This resulted in that luminescence was excited not by separate lines, but by a wide set of wavelengths. Vavilov did not succeed in establishing the relationship between specific luminescence and the wavelength of exciting light, which contradicted Einstein's theory. However, the calculation made it apparent that the deviations that were expected to be observed in accordance with this theory were very inconsiderable under these experimental conditions.

Vavilov first wanted to determine the absolute values of the luminescence efficiency in substances characterized by a greater degree of brightness. This was important because luminescence was regarded as an attractive, though in terms of energy, secondary, phenomenon. It had been firmly established that the absorption of light results mainly in the heating of a body, while only a very small amount of energy is expended to excite its luminescence. Thus, the famous German physicist Hermann Ludwig Ferdinand von Helmholtz thought that the energy required was below 0.1 per cent. The preponderant

opinion was that the use of luminescence for practical purposes had no future.

Accurate measurements of the absolute value of the energy of the absorbed light and the luminescence that emerged were required. Accomplishing this presented a difficult problem.

Vavilov suggested an ingenious method in which the absolute measurements were replaced by the relative ones. With the help of a König-Martens spectrophotometer he compared the intensity of the exciting light emitted by the diffusing surface (a glass plate covered with magnesium oxide) with the intensity of the luminescence that was excited by it. Vavilov took into account the errors of the American physicist Robert Williams Wood who had ignored the fact that the intensity of reflected light depends on the angle of reflection (Lambert's law of emission), whereas luminescence (in accordance with Lommel's law) is equally propagated in all directions.

Vavilov established that with a large number of dyes the efficiency of luminescence could be quite significant. Thus, for aqueous solutions of fluorescein, it is equal to 80%, for an aqueous red solution, 54%, for an aqueous solution of rhodamine G, 37%. These results were of fundamental significance since they demonstrated that in terms of energy the luminescent processes play a major, rather than secondary role, and that their emergence calls for a considerable part of the energy of exciting light.

In 1924 Academician D. S. Rozhdestvensky wrote: 'Vavilov's discovery has radically altered our ideas concerning the phenomenon of luminescence and we have to rid ourselves of our former disparaging attitude to its practical application.' Vavilov's results connected with the determination of the absolute values of luminescence efficiency have been used as standards for more than fifty years.

Later Vavilov proposed a thermal method to determine the absolute value of luminescence efficiency. It consisted in comparing the heating of luminescing and non-luminescing solutions during their absorption of an equal amount of energy of exciting light. The practical implementation of this method presented enormous experimental difficulties, which were brought about by the

necessity of being particularly accurate when taking into account all possible losses of heat that could occur during the experiment.

Such subtle measurements were successfully accomplished by Mikhail Nikolaevich Alentsev. He concluded them not long before his teacher died. The values for the absolute efficiency of luminescence that he obtained proved to be nearly the same as those that were obtained by Vavilov in 1924.

Sergei Vavilov returned to this subject in 1927. Only now he conducted the experiments on a much more sophisticated level, covering a wide range of wavelengths—from the ultraviolet region of the spectrum (250 nanometres) to the middle of its visible region (540 nanometres). He made use of a quartz monochromator as a spectral instrument to produce the exciting beams of a specific wavelength, while a mercury lamp served as the source of ultraviolet rays. When the experiment was being carried out in the visible part of the spectrum, a 500-watt projection lamp was employed.

Vavilov experimented mainly with alkaline aqueous solutions of fluorescein, for which he established that the efficiency of luminescence is dependent on the wavelength of exciting light. This relationship, reflecting one of the basic regularities of molecular luminescence, has acquired the name of Vavilov's law. It turned out that within the interval from 250 to 430 nanometres the efficiency of luminescence increases proportionally to the wavelength of exciting light, while in the interval ranging from 430 to 515 nanometres, it remains constant, after which it starts to drop rapidly.

Vavilov's law can find its explanation in the quantum concepts of the nature of light phenomena. The increase in the energy efficiency of the glow proportional to the wavelength of exciting light signifies the constant character of the quantum efficiency of luminescence. The experimental verification of Vavilov's law concerning the quantum efficiency of luminescence for various substances has fully substantiated this law.

For each compound there is a vast region of wavelengths of exciting light, where the quantum efficiency of the glow remains constant. This means that the number of radiated quanta of luminescence increases in proportion to the number of absorbed exciting quanta. This kind of

relationship becomes apparent within the whole range of the Stokes region of the spectrum.

As far back as 1852 the English physicist George Gabriel Stokes established that the wavelength of luminescence is always greater than that of the exciting radiation.

According to Stokes, the spectrum of luminescence has to be shifted as regards the absorption spectrum in the direction of the long waves. However, with most substances the spectra of absorption and luminescence overlap each other in part. The region of the luminescence spectrum where the frequencies exceed those of the exciting light is referred to as the anti-Stokes region. The long-wave region of the luminescence spectrum, however, where Stokes' rule is strictly observed, bears the name of the English scientist. During the transition to the anti-Stokes region, the luminescence quanta become greater than the exciting quanta. Their emergence can find its explanation in the combination of the quanta of exciting light with the vibrational energy stored in the molecules prior to their excitation.

The most difficult problem was the reason for the decrease in the efficiency of luminescence in the anti-Stokes region of the spectrum. Vavilov was profoundly concerned with the nature of this phenomenon. His last paper entitled 'On the factors conditioning the decrease of luminescence efficiency in the anti-Stokes region' was devoted to this particular problem. He wrote it not long before his death in the beginning of January 1951, and sent it for publication to the periodical *Reports of the USSR Academy of Sciences.* Within several days he came up with new ideas and decided to introduce some changes into his article. On the last day of his life the proofs never to be amended were still lying on his desk. The article was published with no changes in 1952.

In the following years this problem was not infrequently discussed. The Byelorussian physicists Nikolai Borisevich, Viktor Gruzinsky, and Vitali Tolkachev and later Georgi Gurinovich, Elena Kruglik and Anton Sevchenko proved that when the experiment is being carried out under conditions excluding the formation of new centres of absorption and luminescence in vapours and solutions, the quantum efficiency of the glow remains constant even when luminescence is produced in the anti-Stokes region of the spectrum.

Vavilov established that the luminescence efficiency of a large number of substances is to a large extent dependent on external effects. Under the external effects it usually decreases markedly, which indicates a decrease in the energy efficiency of the luminescent substance. In cases like these we say that luminescence is quenched. What Vavilov primarily investigated was the quenching that arises when the concentration of a substance in a solution decreases. This phenomenon had long been known. Its qualitative aspect had been studied as early as the middle of the nineteenth century by George Stokes himself. However, in quantitative terms, the course of the process had not been determined.

In 1934 Vavilov analyzed the concentration quenching of luminescence with a number of dyes dissolved in various solvents and derived a formula that adequately described the course of this process within a wide range of concentrations. According to this formula, within a particular interval of concentrations, the glow efficiency remains constant, after which, on reaching the concentration threshold, which has a characteristic value for each substance, an exponential decrease occurs.

As is known, the luminescence efficiency can markedly decrease in those cases when foreign admixtures are introduced into the solution. This type of luminescence quenching had also drawn Vavilov's attention. In 1934 together with his pupil, the future Academician Ilya Mikhailovich Frank, he proposed a theory explaining this phenomenon. Later this theory was further developed by Boris Sveshnikov who was also one of Vavilov's pupils.

A thorough study of the processes resulting in the luminescence quenching made it possible for Vavilov to classify them. He divided all the known types of quenching as belonging to either the first or second class. To the former he referred processes where the decrease of luminescence efficiency was brought about by the effect on non-excited molecules; the latter class was conditioned by the effect exerted upon the excited molecules. The quenching of the first type does not affect the average duration of the excited state of molecules, whereas that of the second should be accompanied by a decrease in duration.

As is actually the case, each molecule that has reached an excited state remains in that state for a certain

period of time, which is greater for some molecules than for others. Experiments reveal a synchronous glow for a very large number of molecules, for which reason the duration of the excited state is characterized by an average time for all molecules. Under the activity of inhibition factors the molecules spending the longest period of time in an excited state will be the first to be affected. This is exactly what causes a decrease in the average duration of the excited state of the molecules under investigation.

Vavilov's research proved that provided the decay of the glow occurs exponentially and the character of its inhibition is exponential, there should exist a proportional relationship between the efficiency of luminescence and the average duration of the excited state of the molecules investigated. The constancy or variation of the value in the average duration of the excited state of molecules can serve as a graphic criterion revealing the nature of the inhibition of their glow.

Research connected with polarized luminescence occupies a considerable place in Vavilov's scientific activity. In 1921 Vavilov made Vadim Levshin, the physicist who has already been mentioned here several times, his immediate associate in studies on luminescence. Over a period of thirty years Levshin was Vavilov's closest colleague, and, in the words of Academician Vassili Vladimirovich Shuleikin, 'his inseparable companion in science'.

Vavilov's pupil Pyotr Feofilov wrote: 'They were people whose temperaments were quite different in many respects, and as they complemented each other, their cooperation over a period of a number of years was most fruitful. ' After Vavilov's death Levshin took over the responsibility for Vavilov's laboratory at the Lebedev Physical Institute of the USSR Academy of Sciences.

One of the fundamental properties of optical radiation is the polarization of light. This term was introduced in science as far back as 1808 by the French physicist Étienne Stephen Louis Malus. However, for the concept of the polarization of light itself, we are wholly indebted to Sir Isaac Newton, who based his conclusions on research that had been carried out by the Danish mathematician and specialist in medicine Erasm Bartholinus, who in 1609 discovered the phenomenon of birefringence in crystals, as well as on that of the Dutch optician Chris-

tian Huygens, who tried to interpret this phenomenon in terms of theory.

The essential principle of the polarization of light consists in the non-uniformity of various vibrations in the plane that is perpendicular to the direction in which the light beam is propagated. If such non-uniformity is absent, the light is called non-polarized, or natural. This is one of the extreme cases. The other one is when within this plane the vibrations take place only in one direction. This kind of light is referred to as its linearly polarized variety. The intermediate cases that are most often found in practice correspond to what may be called partially polarized light. The polarization of light can be described in quantitative terms with the help of a characteristic which is known as the degree of the polarization of light. Its value ranges from 0 (natural light) to 100% (linearly polarized light).

In studies on luminescence the polarization of light had for a long time remained unnoticed by anyone. It was only in 1920 that the German physicist Fritz Weigert reported that he had managed to discover polarized luminescence in some dye solutions. This information drew the attention of Vavilov, who in 1921, together with Levshin, began studying polarized luminescence. In later years Levshin used to recall that Vavilov and he argued a lot over the results that were obtained.

In 1923, based on the analysis of twenty-six dye solutions the researchers confirmed the existence of polarized luminescence. The quantitative dependence of the polarization of the glow on the viscosity of the solution was thus established. Vavilov and Levshin proved that there is a maximum polarization that is characteristic of each substance and does not usually exceed 40%. They established that polarized luminescence is not exclusively observed when the glow is excited by linearly polarized light, i.e. it can also manifest itself when the luminescence is produced by non-polarized beams.

A formula was deduced which connected the polarization when the glow was excited by ordinary light with its value observed when the luminescence was produced by linearly polarized light. The Vavilov-Levshin formula, which has been experimentally confirmed many times over, helps, depending on the required conditions of the experiment, to effect the excitation of the glow by both

ordinary and polarized light, which widens the experimental possibilities to a marked degree.

Vavilov and Levshin had theoretically analyzed the simplest cases of polarized luminescence by assuming that the absorption and emission of light in a molecule can be described by regarding it as an electric dipole, or the sum total of two electric charges of equal magnitude and opposite sign placed at a short distance apart, that is small as compared with the distance of these charges from the points of the field that are under investigation. It was considered that the dipoles, responsible for absorption and emission are identical. With these concepts serving as the starting point, it was possible to obtain 50 per cent polarization when dipoles were uniformly distributed in space. This value proved to be close to that of the ultimate degree of polarization with a number of substances.

In 1924 Levshin discovered that the ultimate degree of polarization was to a great extent dependent on the wavelength of exciting light. However, imperfect equipment made it impossible to study this highly important regularity. It was only five years later that Vavilov could avail himself of the opportunity to analyze this phenomenon on a much more sophisticated experimental level. He made use of the same diluted glycerine solutions of dyes (10^{-5} g per cu. cm) that were used by Levshin. A quarter mercury lamp served as the source of light for wavelengths between 540 and 253 nanometres while an arc carbon lamp was the source for wavelengths between 250 and 200 nanometres. Individual waves were isolated by means of a quartz monochromator.

Elaborate measurements over a wide spectral range had led Vavilov to the discovery of an important relationship between the ultimate degree of polarization and the wavelength of exciting light. Vavilov showed that the degree of polarization tended to vary greatly when the wavelength of exciting light underwent alterations, and in a number of cases it could acquire a negative value. It occurred that this relationship was characteristic of each luminescent substance. This enabled Vavilov to introduce a new optical characteristic of luminescent compounds, which he called the polarized spectrum. Nowadays the polarized spectrum along with the spectra of absorption and luminescence are widely employed when the properties of luminescent substances are studied.

Vadim Levshin, and later, the French scientist Francis Perrin developed the theory of polarized luminescence. Quite independently they arrived at an important formula known as the Levshin-Perrin formula, which connects the observed polarization of luminescence with the angle between the absorbing and emitting dipoles in a molecule.

The ensuing experiments carried out by P. Feofilov proved that the polarization spectrum of a substance was very closely connected with its electronic spectrum of absorption. By using the Levshin-Perrin formula, Feofilov established that the polarization spectra help to determine the relative position of the dipoles of absorption and emission in molecules, which makes it possible to obtain information on the properties of molecular systems that no other methods can provide.

While studying polarized luminescence Vavilov became interested in the nature of the so-called elementary radiators. He proved that the absorption and emission of light by such complicated systems as atoms and molecules could be described by equating them with certain simplified models, or elementary radiators. The functions of such models could be performed by electric dipoles and magnetic dipoles (which differ from the electric ones in that within them the electric charges are replaced by the sum total of two magnetically charged particles of equal magnitude and opposite sign) as well as by the electric quadrupoles, or systems of charges, representing two equal and opposite electric dipoles placed at a very short distance apart. It occurred that it was superfluous to introduce into the description more complicated models of elementary radiators. However, in the case of simplified models, the systems of radiation in molecules can also prove to be fairly complicated since one is often bound to assume that the radiating and absorbing elementary radiators are not identical.

Vavilov proposed two ingenious and sensitive methods for determining the nature of elementary radiators. The first was based on the observation of the interference of light beams diverging from the source of light at a very large angle and then meeting at the point of their convergence. The studies on wide-angle interference were carried out by S. Vavilov and E. Brumberg between 1932 and 1937. The essence of the method of wide angle

interference consists in that each of the elementary radiators has its own characteristic distribution of intensity of the emitted light in space. This results in that the interference pattern of the beams emitted by the radiators is determined by the angle between them. In addition to this its character greatly depends on whether the intensity of the beams is the same or different. When the intensity is the same and the difference in phases is appropriate, the beams can completely extinguish each other. Otherwise, this phenomenon does not take place. Calculations made it apparent that during the interaction of widely divergent coherent beams the interference patterns should be markedly different in the cases of dipole and quadrupole radiation. This method helped to reliably establish the nature of elementary radiators.

The other method for determining the nature of elementary radiators as suggested by Vavilov in 1940 is based on the comparison of the polarization of the glow of elementary radiators of dissimilar nature. Theoretical calculations made it possible to establish the relationship between the polarization of the glow and the angles of observation as well as the angles that determine the direction of vibrations of exciting linearly polarized light if the absorbing and radiating systems are the electric dipoles, quadrupoles, or their combination.

For all these cases Vavilov calculated the curves that characterize the relationship between the luminescence polarization and the aforesaid angles. He called these curves polarization diagrams. The method of polarization diagrams proved to be extremely fecund. It was successfully employed by a large number of scientists, and its application made it possible to determine the nature of the elementary radiators of many luminescent substances in solutions and molecular crystals.

Vavilov also extensively studied the duration of the afterglow of molecules. He wrote his first work in this field with Levshin in 1925. It was devoted to investigations on the relationship between fluorescence and phosphorescence in solid and liquid media.

The division of luminescence phenomena into fluorescence and phosphorescence is fairly tentative. Fluorescence is usually defined as the short-term processes of the glow, which decay upon the cessation of excitation, while phosphorescence is understood to be the processes

pertaining to the long-term afterglow, which continues for a noticeable period of time after the exciting radiation has ceased.

It was known that many dyes placed in viscous media such as, for instance, gelatine films or frozen solutions, exhibited continuous afterglow, whereas in unfrozen solutions their glow was completely extinguished within a billionth of a second. What had been predominant in science for a long time was the viewpoint of the German physicist Egon Alfred Joseph Wiedemann, in accordance with which the transition from the short-term afterglow (fluorescence) to the long-term afterglow (phosphorescence) was caused by a change in the viscosity of a solvent and it took place gradually as the viscosity increased.

With the aim of verifying these concepts Vavilov and Levshin designed two original instruments (phosphoroscopes) that were meant to measure the short-duration afterglow. One of them presented an ingenious modification of the well-known one-disc phosphoroscope of the French physicist A. H. Becquerel. It enabled the researchers to measure the duration of afterglow over a long period of time—from 10^{-2} to $4 \cdot 10^{-5}$ s. What presented even greater interest was the second pulse electric phosphoroscope with a rotating mirror, which was designed for measuring short-duration processes that were taking place over a period of time ranging from 10^{-4} to 10^{-6} s. This instrument clearly presented an enormous step forward in the technology of phosphoroscopic observations.

The excitation of the glow was produced by the condensed electric discharge of three capacitors connected in parallel (Leyden jars). The discharge continued for not more than 10^{-6} s. The glow continued its development in time with the help of a rotating mirror whose speed of rotation did not exceed 25 revolutions per second. The measurement of the intensity of the glow in the process of its development within different sections was measured by photographic means.

With the help of their phosphoroscopes Vavilov and Levshin analyzed the glow of a series of dyes in such viscous media as castor oil, thick sugar syrup, gelatine jelly, and the solution of celluloid in acetone. They proved that what was assumed by Wiedemann to be a gradual transition from the short- to long-term glow did

not exist as such. Each of these processes develops independently and phosphorescence emerges only in either solid bodies or highly viscous liquids.

In what came later it was shown that the emergence of continuous afterglow is conditioned by the fact that the molecules under investigation that are found to be in solid media tend to change to a peculiar excited state called the metastable state, from wich all possible transitions to the lower states are forbidden transitions. The presence of excited molecules in the metastable state markedly increases the duration of the afterglow.

The researchers found that many dyes were characterized by a continuous afterglow in sugar fruit-drops (sugar phosphorus). Ever since then a sugar medium has been widely used when the phosphorescence of complex organic molecules was to be studied.

The research carried out by Vavilov and Levshin gave rise to a new direction in optics known as spectroscopy of the triplet (metastable) state of molecules, which drew the attention of a large number of scientists in the USSR and elsewhere.

Soon after this research was completed Vavilov went on a scientific mission to Germany. For the period of six months he worked at Berlin University in the laboratory of Professor Peter Pringsheim. When he was still in Moscow, Vavilov developed a plan for further research on the continuous afterglow of complex organic molecules. He fully availed himself of the experimental possibilities provided by Pringsheim's laboratory, which had much better facilities than his own.

Vavilov worked entirely by himself, though he made use of Pringsheim's laboratory equipment, discussed a number of questions with him, and considered it his duty to make the German scientist his coauthor. In 1926 the paper by Vavilov and P. Pringsheim 'The polarized and nonpolarized phosphorescence of the solid solutions of dyes' appeared. It was devoted to the afterglow of sugar phosphoruses of a great number of dyes. The subject under discussion concerned two types of persistent afterglow; one being the polarized variety with its spectrum wholly coinciding with that of the short-duration glow, or fluorescence, and the other, the nonpolarized one, coinciding with the phosphorescence spectrum, which is shifted in the direction of the long waves as compared

with the fluorescence spectrum, and consequently, with the spectrum of primary afterglow as well.

The data presented in the article enabled the Polish physicist Alexander Jablonsky to work out a scheme in 1935, which qualitatively explained the origin of the persistent afterglow of organic molecules in solid media. In their turn, the results achieved by Jablonsky served as the basis for the creation of a complete scheme of these processes, which was elaborated in the forties of the present century by Aleksandr Terenin and the American physicist Gilbert Newton Lewis quite independently of each other. This scheme gave rise to the contemporary concepts of the nature of persistent afterglow in molecular systems.

Vavilov had always striven for large-scale theoretical generalizations based on experimental data. In 1934 he advanced a classification of the types of luminescence according to the character of their kinetic properties. This classification divided the types of luminescence into three groups: the spontaneous glow, induced, or metastable glow, and recombination glow.

The spontaneous glow is characterized by exponential decay, where the velocity of decay is independent of temperature. The induced variety of the glow also ceases exponentially, though the velocity of the decay is most markedly dependent on temperature. The recombination glow arises at the expense of the energy emitted by recombining particles that were separated during the absorption of the quanta of exciting light, and its decay is hyperbolic. Vavilov's classification was of principal significance since it was the first to reveal the fundamental elementary stages of the glow.

The year 1928 saw the publication of a very large study by Vavilov and Levshin entitled: *A study of the nature of the photoluminescence of uranyl salts.* The research focused on crystals of uranyl salts, uranium glass, and liquid solutions of uranyl compounds. In the paper the authors proved the conceptions held by American physicist Ernest Fox Nichols and his colleagues to be erroneous. They had considered that the decay of the glow of uranyl salts could be described by the sum of a large number of hyperbolic functions (which would have served as proof in favour of the recombinative nature of the glow of such compounds). Vavilov and Levshin made it abun-

dantly clear that the decay of uranyl compounds occurs exponentially and that their glow is not of recombinative, but of molecular character.

By the end of the thirties the number of studies on luminescence undertaken in the Soviet Union had greatly increased. Vavilov and his scientific school discovered and conducted research on the most important laws governing the molecular glow, and a vast amount of experimental data was accumulated, which called for a theoretical generalization. Particularly interesting and varied effects were observed in concentrated solutions of complex organic compounds, where the concentration of the molecules of a dissolved substance resulted in marked changes in their basic optical properties.

Vavilov understood that it had become necessary to consider various concentration phenomena of luminescence from a single point of view. In the beginning of the forties he took the first steps towards creating a general theory of concentration effects in solutions of luminescent compounds. His first research along those lines was accomplished in collaboration with P. Feofilov at the State Optics Institute in 1942. The further development and experimental verification of this theory had a pivotal role in Vavilov's scientific activity in the years that followed.

An increase in the concentration of solutions of various ogranic luminescent substances leads to a whole series of effects, viz. the depolarization of the glow (concentration depolarization), a drop in the efficiency of luminescence (concentration quenching), and a decrease in the average duration of the excited state of luminescent molecules. The concentration effects are found to be highly complex and varied. It is not surprising, therefore, that for many years the scientists could not advance any satisfactory theory explaining them.

In 1927 the French physicist Jean Baptiste Perrin pointed out the fundamental possibility of non-radiative transmission (by induction) of the absorbed light energy from an excited to a non-excited molecule. Two years later the German scientists Hartmut Paul Kalman and Fritz Wolfgang London elaborated a theory that explained the concentration depolarization of resonance radiation of natrium vapour. What they considered to be the reason for depolarization was the transmission of excita-

tion energy from one molecule to another. This energy increased as the density of the gas under analysis increased. Subsequently Francis Perrin, implementing his father's idea and applying the concepts suggested by Kalman and London to liquids, developed the theory of the concentration depolarization of the luminescence of solutions. However, this theory contained a number of simplified concepts that were not experimentally substantiated.

Vavilov made use of the tenable concepts of these scientists concerning the possibility of migration of excitation energy in solutions between contiguous molecules. He refuted a number of assertions that had proved to be substantial shortcomings in the preceding theories and had led their authors to erroneous results. In fact, Vavilov confined himself to the investigation of purely physical processes in solutions, considering the spectra of absorption and luminescence to be independent of concentration. As later became apparent, this proved to be the case for only a rather narrow range of concentrations. Vavilov believed that the phenomenon of concentration depolarization and concentration quenching of luminescence are closely connected with each other and take place when the molecules are in an excited state.

Sergei Vavilov, Mikhail Galanin, and Faina Pekerman presented experimental proof of the presence of a resonance induction bond between molecules in their paper 'Experimental studies of energy migration in fluorescent solutions' (1949). They established that the migration of energy becomes more intense in accordance with the extent to which the absorption and luminescence spectra are superposed on each other, i.e. the greater the resonance interaction between the molecules tends to be. With substances whose absorption and luminescence spectra do not overlap, and consequently, in which case the resonance interaction between the molecules is absent, the quenching of the glow is not observed at all.

In those instances that are characterized by the superposition of absorption and luminescence spectra when the concentrations of solutions are markedly high and when the distance between the molecules becomes much smaller than the wavelength of radiated light, the molecules begin to interact, which results in the migration of excitation energy and in the phenomena that have already

been described. As has been mentioned, in the majority of cases the molecules could be regarded as electric dipoles, which radiate polarized light. If it were taken into account that in a solution the molecules are arranged chaotically and that by their nature they are anisotropic, then the inevitable consequence of the migration of excitation energy would be either a greater or a lesser depolarization of the glow.

Furthermore, in Vavilov's opinion, energy migration and subsequent radiation should be accompanied by certain energy losses. In this case part of the excitation energy will be converted into heat, which will lead to the quenching of luminescence. It is but natural that the probability of this kind of energy transfer is greater with molecules characterized by a persistent afterglow, and hence they will decay first. This will be followed by a decrease in the average duration of the excited state of the molecules under investigation.

From Vavilov's theory of migration there issued a number of consequences, which could also be verified experimentally and serve to substantiate the tenability of the theory. In 1944 this theory enabled Vavilov to prognosticate the existence of a new phenomenon, viz. the depolarization of luminescence according to its decay. This phenomenon was soon discovered by his pupils Anton Sevchenko (with uranyl glasses) and Mikhail Galanin (with solutions of some dyes).

The theory of energy migration also explains the quenching of the luminescence of dye solutions by extraneous absorbing substances (which have colour, and consequently an intense absorption band in the visible region of the spectrum). In 1949 S. Vavilov and M. Galanin pointed out that the quenching of luminescence by means of resonance could be brought about by any extraneous nonluminescent molecules that are found to be at sufficiently short distance from the excited molecules.

The only condition underlying the transfer of energy between them and accordingly the existence of this type of glow quenching is the presence of an inductive interaction between these molecules. The greater the extent to which the luminescence spectrum of an excited molecule is superposed upon the absorption spectrum of quenching, the more marked the quenching should be.

If the extraneous molecules do not possess luminescent

properties, then all the excitation energy obtained by means of resonance will be converted into heat. However, when such molecules do possess luminescent properties they are bound to emit their own glow. This phenomenon has been called sensitized luminescence. The reverse effect of extraneous molecules on the excited molecules of a luminescent substance should result in a decrease in the duration of the latter's afterglow duration.

As had been suggested by Vavilov, the quenching by extraneous absorbing nonluminescent substances was studied by Galanin and Levshin. The results that they obtained fully confirmed what had been prognosticated by Vavilov. The German physicist Theodore Foerster, and later Galanin experimentally discovered and studied the phenomenon of sensitizing luminescence.

Vavilov's series of studies on the migration theory of concentration effects was highly appreciated. In 1943 the scientist was awarded the USSR State Prize for his research in this field.

In spite of the enormous success of the migration theory, it was nevertheless not able to explain a large number of concentration phenomena. Thus, from its standpoint it remained impossible to understand the concentration changes in the absorption and luminescence spectra; moreover, the nature of the concentration quenching of luminescence remained unclear and the assumption concerning the quenching when the energy is being transferred from one excited molecule to another called for further evidence.

In the following years V. Levshin and the author of the present book proved that the development of concentration effects was greatly influenced by the formation in the solutions of nonluminescent associated molecules of the substances under analysis. The merging of Vavilov's migration concepts with the theory of molecular association made it possible to interpret the whole range of central phenomena in the solutions of complex organic compounds.

Vavilov's ideas as regards the migration of excitation energy proved to be extremely fecund. Nowadays they are widely implemented when it comes to the interpretation of processes that occur in molecular crystals. These ideas are very significant for the comprehension of a large number of biochemical phenomena as, for instance,

the problems of photosynthesis; they are successfully employed for practical purposes when working with organic substances that ignite under the influence of nuclear radiation and elementary particles, as well as when it is necessary to obtain highly effective media for the lasers functioning on dyes with a smoothly adjustable frequency of generation, etc.

In characterizing this particular series of investigations by Vavilov, the outstanding Soviet photochemist A. Terenin wrote: 'The studies on luminescence carried out by Sergei Vavilov and his scientific school have to a great extent determined the development of world science in this field of studies with themselves taking the lead.'

THE ACQUAINTANCE WITH GERMAN PHYSICS

Though the standard of living in the country was very low in the twenties, the development of science received all the attention it deserved. A large number of Soviet scientists were sent on scientific missions to other countries with the aim of acquainting themselves with foreign methods of research. Among them was Sergei Vavilov. In January 1926, as the first professor whose work received very high approbation, he was given the opportunity to go to Germany for six months, as was already mentioned. It was the time when Vavilov was head of the laboratory of physical optics at the Physics and Biophysics Institute of the RSFSR Peoples' Health Commissariat and was also professor at the Bauman Moscow Higher Technical School and Moscow Higher Zootechnical Institute.

Very little was known about this period of Vavilov's life and the author of the present book could not but avail himself of the opportunity to fill the gap.

Sergei Vavilov regularly wrote to Vadim Levshin from Germany, and each letter was a detailed account of his life, impressions, work, successes, and failures. He shared his ideas, plans and doubts with his friend. All of these letters to Levshin from Germany had remained safe in the author's home archives and had thus been made available to him.

Aleksandr Ivanovich Herzen once wrote: '... letters— ... are more valuable than reminiscences—they bear the

clotted blood of the events and are the past itself, remaining, as it was, forever undecayed.' When we read Vavilov's letters we become familiar with his creative laboratory, and learn a great many interesting facts about the situation that prevailed in the scientific circles of Germany—the then acknowledged world centre of science—at the time when quantum and mechanical concepts of the nature of light and substance in physics were beginning to gain ground.

In Berlin, and later in Göttingen, Vavilov had the opportunity to mix with many of the outstanding physicists of his day. He also had the chance to meet them in their home surroundings, and their merits as well as human foibles did not escape his keen eye. Vavilov's letters are primarily interesting in that they help to provide us with additional information on the great men of science and reflect not only their creative, but also their purely human qualities.

At first Vavilov was not particularly impressed with P. Pringsheim, in whose laboratory he was to work. In the very first letter to Levshin he wrote: 'I saw Pringsheim today ... there is something about him that makes me think of Bachinsky*, though he looks more stupid. We have already argued over something.' In the next letter he continues: 'On the second day of my arrival I went to the Physics Institute... Ran right into Pringsheim on the stairs. He is clean-shaven, tall, bald, looks emaciated, and presents, altogether, rather a mildewy appearance. He commented on my having come late... it is the fourth day now that we have been carrying on our discussions of fluorescence. I can assure you that he's no genius and what we thought of him back in Moscow was presumably quite right. He gets hold of everything that others fail to keep their eyes on and makes use of it.' Later, however, Vavilov and Pringsheim became very good friends.

By the time Vavilov was to go abroad, he, though young, was already known through his works far beyond his own country. When he came to Germany, he acquainted Pringsheim with his plan of research and wrote to Levshin about the impression his first talk with the German physicist produced upon him: 'Pringsheim's atti-

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* A. I. Bachinsky—a professor at Moscow University and Levshin's scientific adviser.

tude to our research, in general, and to our latest work, in particular, is highly favourable.'

Vavilov's plans were endorsed and it didn't take him much time to do an important part of his research on the polarized properties of the persistent glow of sugar fruit-drops and various dyes, which was mentioned previously. In compliance with what was preconditioned by Pringsheim, Vavilov had to follow up the research conducted by the American physicist R. Wood on the variation of the absorption of mercury vapour when extraneous gases were added to them.

Vavilov had to agree to this though it was far from what he desired. This is what he wrote about Pringsheim's condition: 'I'm not particularly fond of this subject, but what he has is equipment and I do cherish some hope that I might find something quite new. I shall work in Pringsheim's room, which, you will be pleased to know, is dirtier than our own laboratory back home.'

Thus Vavilov was simultaneously to undertake the study of two different subjects. His scientific intuition did not fail him. His research along the lines of the first trend soon proved to be successful. However, the theme suggested by Pringsheim required that a large number of experimental difficulties be overcome and did not bring any tangible results.

Vavilov regularly attended seminars in physics held at the Berlin University. These sessions were conducted by the Nobel Prize winner Max von Laue. Those who actively participated in the meetings included the Nobel Prize winners Albert Einstein, Max Planck, Walter Nernst, and other prominent physicists. The discussions were about the newly published research of the French physicist Louis Victor de Broglie, the Austrian physicist Erwin Schrödinger, the German physicists Werner Karl Heisenberg, Max Born and P. Jordan. All these works were devoted to quantum mechanics which was at that time not yet acknowledged. Vavilov wrote the following about one of such sessions: 'Today I was present at a highly authoritative seminar in the main auditorium. The speaker was a certain Gordon. Heisenberg's subject was taken up again, and once more nobody understood anything. Among those who attended the meeting were Nernst, Planck, Laue, Einstein and other celebrities.'

A soft smile is seen behind many of these letters:

'On the very first day I came to the Institute I found myself at a seminar with about six other people that included Laue, Pringsheim, Hattner, Cherny, and Ortman. The discussion was centred round Heisenberg's work. I failed to grasp anything, and I think that others were in the dark too, except Laue, who had previously read Heisenberg's article supplied with comments. This kind of seminar is very much the same as ours in optics. Nobody seems to blush to actually read the articles... I attend the seminars regularly... Among those who are always present are Planck, Einstein, Laue, Bothe, and others. The speakers take their time, go into minute details, but sound very dry... Pringsheim introduced me to Nernst (a small, very pleasant-looking old man), who, it occurred, was quite sure that P. Lazarev was a physiologist! Then we went to Nernst's lecture on the general course in physics (on reaching old age he became Director of the Physics Institute and it is the first time that he is trying to give lectures on physics). He was discussing the passage of electricity through gases, and I think that essentially his lecture was unsatisfactory. That day in the afternoon I was priviledged to behold another luminary—Einstein. He was delivering a popular lecture on relativity in the main auditorium. It was really splendid! He produces the impression of an obese tomcat, with thick hands and very narrow eyes. Today I was introduced to Einstein and had the honour to accompany him along Friedrichstrasse. Last night I went to see Pringsheim at home and met his wife. Their flat looks rather shabby, though he says that his salary amounts to 800 marks a month.'

The young scientist did not have the courage to appear with his work before so celebrated an audience. However, in the middle of May 1926 the members of the seminar did have the chance to acquaint themselves with the results that had been achieved by Vavilov and Levshin in their studies on the fluorescence and phosphorescence of dyes.

This is what Vavilov wrote about this particular event:

'Yesterday Pringsheim's seminar heard me speak about the work you and I are doing. I was asked to do so immediately on my arrival here, but I either refused to do so, or had it postponed. I don't think there is any plea-

sure in mumbling before the great ones of this world. That was why Pringsheim decided to talk about it himself. What he said was not bad at all, though he did make a mess of it by turning everything upside-down, and began to speak first of the uranium glass. All the elite were there, i.e. Einstein, Nernst, Planck, Laue, to say nothing of the young Bothe, Bose, Ladenburg, and others. Pringsheim was making lavish use of such epithets as 'remarkable', 'how ingenious', 'impressive', thus producing a spellbound effect upon the audience. Between ourselves, I think there is nothing we should be particularly modest about since what I heard people whisper during the report was "splendid" and a lot more of the same kind of appraisal. The "Master" himself, I mean Einstein, interrupted the speaker in the middle of his speech and asked him his traditional question, which he usually puts when there is something that he finds interesting: "And where has it been done?"'

It was Vavilov's aim to get to the very bottom of how scientific research was organized in Germany. He not only became fully acquainted with the basic research that was conducted at the Physics Institute of Berlin University, but also visited the Kaiser Wilhelm Institute of Physical Studies in Dahlem, where he saw the laboratory of the outstanding German physicist, the Nobel Prize winner Professor Otto Han and his assistant the Austrian physicist Professor Lise Meitner.

The trip to Dahlem produced a great impression on Vavilov:

'On March 9 I went to Dahlem. It is outside the city. The buildings look like villas, with green lawns and everything in apple-pie order, as one expects to see in a suburban residential area. I visited three small houses (again with Pringsheim, who is very kind indeed). In one of such cottages the director is Han, the "woman director" is Meitner. She was the one who showed the place to us. What she is doing is very serious and conducted with utmost care. In the long run, all this is very much the same as we find with Rutherford, though he himself would not be able to do it so well. All the three departments are essentially chemical ones, and the physicists are working illegally, so to speak. But just watch them do it !... Now that I have seen all this, I begin to look at things in quite a different light. Unfortunately, one cannot describe ev-

erything in a single letter. Let's look forward to having a good long chat when we meet again. All I can say is that Dahlem is a wonderful place'.

On acquainting himself with the physics laboratories, Vavilov was overwhelmed to discover that his German colleagues had remarkable optical and electrical facilities, a vast set of high-grade chemical reagents, and physics periodicals, where they could practically in no time publish their own works. All this provided every opportunity to carry out wide-scale research in various fields of physics.

However, the researches by many Soviet scientists, in spite of the unfavourable conditions in which they were conducted, and primarily those of Vavilov himself and his colleagues, were in the foremost ranks of science, and their results often surpassed the researches that were conducted by foreign scientists. What soaring heights could be achieved were the Soviet physics equipped with the most up-to-date facilities?

Vavilov made every effort to know as much as possible about the methods that were employed by German physicists and to study the possibilities of the instruments that were at their disposal. With this in mind he visited the famous optical plants of Zeiss, Füss and a number of others, where he had talks with their representatives wishing to encourage their trips to Moscow for official discussions on the supply of physical instruments to the Soviet Union.

'I recently visited Zeiss together with Pringsheim and again my mouth was watering. My God! Is there anything that they don't have? One sees the arcs themselves on every single table, and then there are polarization setups, interferometers, and unimaginable episcopes and epidiascopes. How well they would do at the seminars! Here at our colloquiums we have all kinds of tables and pictures from books projected with an epidiascope...'

In another letter he wrote:

'Three days ago I went to see the Füss plant, where I spent the whole day. I was their guest and they showed me absolutely everything—from storehouses to workshops. There was no stint of food, drink, and kind words. What lies at the bottom of all this is quite clear. They want to have business contacts with us. When they heard that a physics congress was to be held in Moscow, they started

asking me to invite their representatives. If possible, ask someone in the Congress Committee to send invitations to the representatives of the most authoritative German plants that produce physical instruments. They are sure to bring catalogues along with them and will certainly be able to supply the necessary instructions. I think that the Congress will only profit by this.'

Vavilov regularly sent to Moscow descriptions and prospects of the most important instruments that were produced in Germany, and he did all he could to have his government buy the most interesting models.

He wrote: 'I am awfully pressed for time. I have no more than 3 or 4 spare hours in the evenings and I am afraid I could not do many things that my colleagues required of me. I haven't seen much either, and on the whole I have not been able to start my work properly and to settle down as such.'

In spite of all this, he did much to help the library of the Physics and Biophysics Institute back in Moscow to expand its collection by keeping in touch with the Institute's librarian Aleksandra Nikolaevna Lebedeva(Pyotr Nikolaevich Lebedev's sister). He informed her of the titles of the German books and the numbers of scientific periodicals that the library would find it useful to have.

Work and life abroad presented quite a few problems. 'Pringsheim is now on holiday and away from home, so I am working all by myself. The Institute is cold-ridden since they don't heat the building when people are on leave. I'm trying to get some warmth from the electric arc rheostat.'

The money always failed to arrive in time and Vavilov was compelled to deprive himself of what was most essential. Sending his thanks to Levshin for all the trouble he took upon himself about money matters, Vavilov could not keep from making a joke of the situation he was in: 'Thank you very much. If it hadn't been for you, I should have found myself in the gutter, or have been sent back to the USSR under the surveillance of the guardians of the law.'

The cold and the meagre rations could not but affect Vavilov's health. In one passage he complained: '... I have recently fallen victim to some kind of excruciating toothache. One may well be surprised that Pringsheim also has the same trouble, though to much lesser degree.

It has already been eight or nine days that I have been haunted by a dental cacophony that prevents me from working properly.' Later he writes: 'Lately I have been feeling feverish and not too well on the whole.'

However, in spite of all the difficulties, Vavilov did not lose his 'joie de vivre'. His letters were replete with optimisms, his plans were enormous and he was impatient to accomplish them as soon as possible. Everything that hindered the progress of his work irritated him. 'Soon it will be Easter here, and I think that for a couple of days I shall have to go somewhere. Nothing can be done about it.' In his letters phrases like the one that follows were not infrequent: 'I am working very much and doing very little.' This can be explained only by the fact that Vavilov made exceptional demands on himself.

Besides Berlin and Dahlem Vavilov had a great wish to visit Göttingen. Financial hardship had for a long time prevented him from making the desired trip, for the sake of which he had even tried to sell his own scientific periodicals. At the end of his stay abroad his dream came true and Vavilov did manage to visit Göttingen.

In those years the small university town was the acknowledged scientific centre of not only Germany but also of all of Europe. Theoretical physics at the Physics Institute of Göttingen University was headed by Max Born, the one at the head of experimental physics was James Franck, and David Gilbert directed the studies in mathematics. The most prominent person was Max Born, who at that time was not more than forty-five years old. He had a pivotal role among a large number of outstanding theoreticians. Among them were Victor Frederick Weiskopf, Werner Karl Heisenberg, Walter Henrich Heitler, Pasqual Jordan, J. Robert Oppenheimer, Wolfgang Pauli, Enrico Fermi, and many other men of science.

Vavilov was most interested in Franck, who had started working in the field of luminescence, and who was about to deliver a corresponding course of lectures to the university students. It was therefore quite natural that Vavilov wanted to meet him and to attend his lectures. He wrote: 'During summer term Franck is giving his course on "Fluorescence and phosphorescence", which I am planning to do myself next year.'

After the hustle and bustle of Berlin, Vavilov found the provincial Göttingen to be a pleasant place of repose. There was no noise from the trams, nor honking of automobiles. What gave the town its local colour were the university undergraduates, who wore caps that singled them out as belonging to a particular student corporation. Traditionally the students behaved freely and noisily and were unrestrained when it came to expressing their own opinions, at times engaging in heated discussions, which not infrequently led to the drawing of their swords. Many students had scars on their faces, of which they seemed to be quite proud. The town awoke early in the morning, and was early to retire for the night. At eleven o'clock the streets were wholly deserted.

Göttingen was surrounded with hills that were thickly covered with trees. Round its central part there was an embankment where many years ago stood the town wall, which was then replaced by a shady alley of old trees.

These were Vavilov's first impressions of Göttingen:

'It is the fourth day that I have been here, and after Berlin I feel as if I were at some kind of resort. This little town looks very much like a garden, with green hills everywhere. The University life seems to permeate its very air, and everything in this little town serves the University's purposes. Each house has plaques (sometimes there are as many as five on the same wall), which remind us of the great people who used to live here. Near the place where I live there is a very nice cemetery, where Gauss is buried. The scarred undergraduates are seen everywhere, there are only three automobiles, three cinemas and three beer bars, but what we have here is Franck, Born, Gilbert and others. I am at the Physics Institute every day, where I am very careful not to miss anything that is of interest there. I really like Franck. We discussed such topics as phosphorescence, polarization and other things that are dear to both of us... I have not yet seen all of his research, I'm becoming acquainted with it bit by bit. By the way there is a V. Kondratyev who was commissioned to do the research here by Ioffe. He is studying nitrogen and is trying to find out what lies behind its dissociation under bombardment by cathode rays and determine its atomic spectrum of nitrogen. I went see Paul today. He is German in all respects and all the things

that he works on are very much the same even as far as their set-ups are concerned. But there is no denying that what is being done is really interesting. I spoke with him about you (I don't think it was out of place). He is quite willing to have you here in case you come. He asked me to see him on Wednesday and tell him about the work you and I have recently been doing. I don't actually look forward to this, but there is nothing I can do about it.'

When Vavilov arrived in Göttingen, three other Soviet physicists were already there: Viktor Kondratyev, who was already mentioned in the Vavilov's letter, Yuri Krutkov, whom Sergei Ivanovich knew very well, and Yakov Frenkel. Krutkov introduced Vavilov to Frenkel. The two scientists found each other's company very pleasant, and after meeting Vavilov, Y. Frenkel wrote to his parents: 'Vavilov, whom I mentioned at the beginning of my letter, is a very congenial person.' In another letter he wrote: 'Yesterday Krutkov, Vavilov, and I went to see Professor Paul, while today we have paid a visit to the Borns. Born, Franck, and Paul are very friendly with each other; they are on first-name terms and on the whole produce the most favourable impression.'

Vavilov's impressions of his contacts with the local theoreticians are also of interest: 'I am now acquainted with Born, attended his lecture on quantum mechanics, and was present at his seminar. I am staying here together with Krutkov and Frenkel. They are enlightening me in the field of all this mystification. The latest news is the theory of Schrödinger and Heisenberg. In short, the ball has started rolling and quite a new era in physics has begun. In any case, all this is higly sophisticated and does not lend itself to comprehension as easily as one would wish.'

Not long before Vavilov left Göttingen he took the floor at a seminar in physics at the University and spoke of the work Levshin and he had been doing on the fluorescence and phosphorescence phenomena in dye solutions. Vavilov described this seminar in his letter: 'Three days ago I reported on our work in the presence of Franck, Paul, Jordan, Frenkel, Krutkov and others. People were interested in what I said and there was much talk about it'.

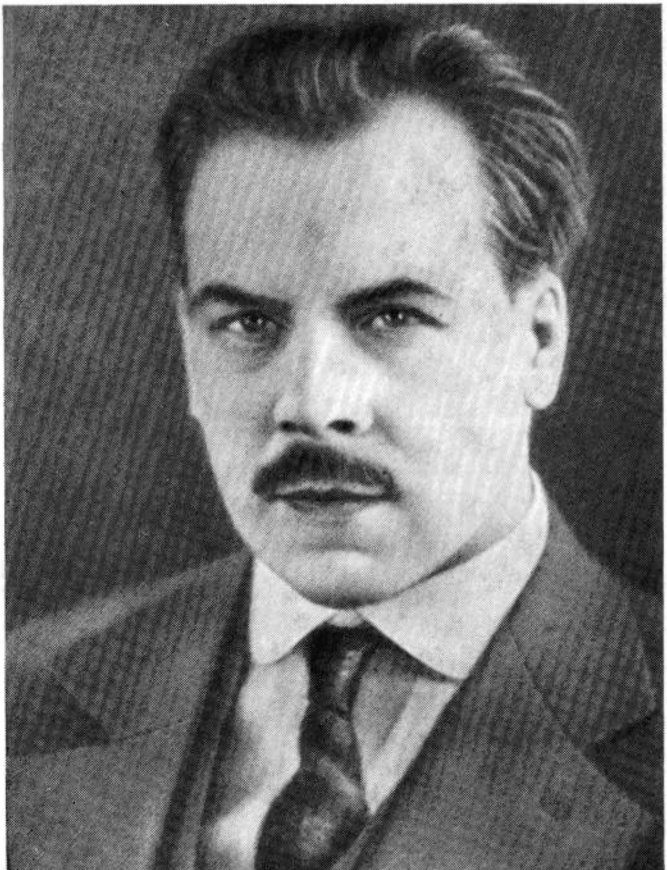
Having accomplished what he had planned to do in Göttingen, Vavilov returned to Berlin, and at the end of

Domna Vasilyevna and Mikhail Asonovich Postnikovs—Vavilov's grandparents on his mother's side.

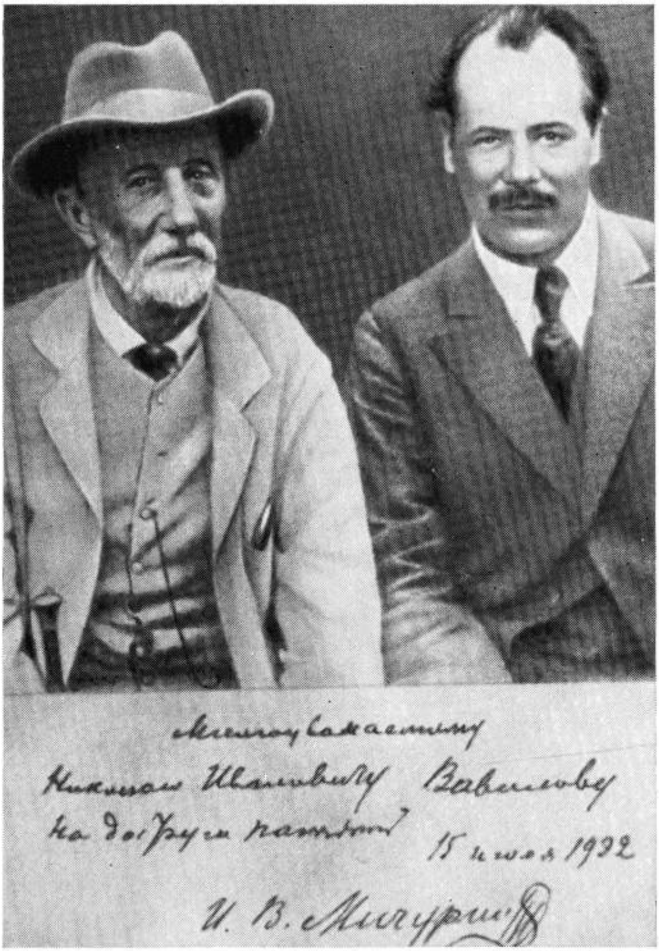
Ivan Ilyich Vavilov, 1928.

Aleksandra Mikhailovna Vavilova, 1937.

Lydia and Aleksandra Vavilovs.



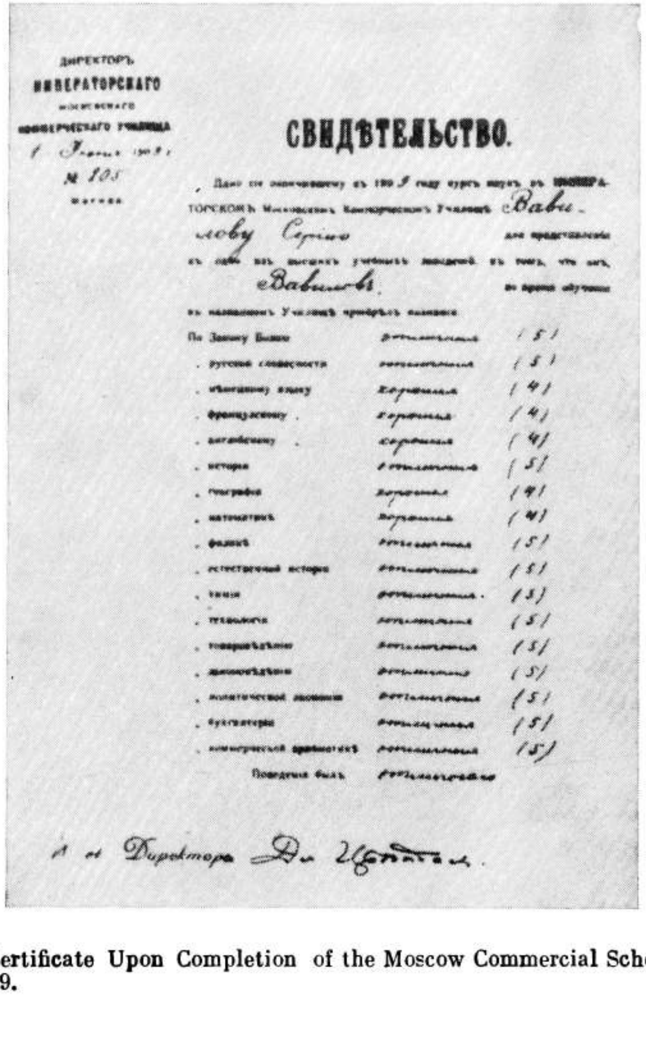
Nikolai Ivanovich Vavilov, 1916.



I. V. Michurin and N. I. Vavilov, 1932.

A. M. Vavilova with her sons Sergei and Nikolai, 1896.

Sergei Vavilov, pupil of the Moscow Commercial School 1906.



ДИРЕКТОРЪ
ИМПЕРАТОРСКАГО
МОСКОВСКАГО
КОММЕРЧЕСКАГО УЧИЛИЩА

№ 105

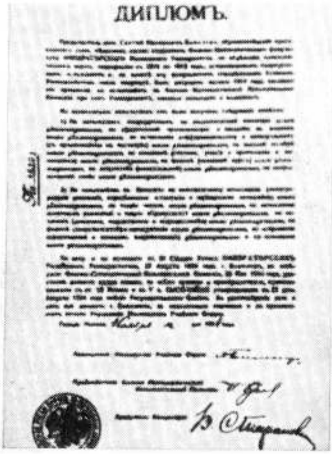
СВИДѢТЕЛЬСТВО.

Вавилову Сергію

Вавиловъ

Certificate Upon Completion of the Moscow Commercial School, 1909.

Sergei Vavilov (the fifth from the left in the top row) with P. Lazarev and a group of students of Moscow University.

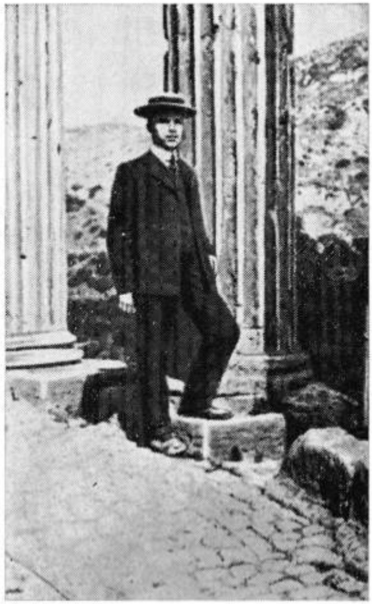


ДИПЛОМЪ.

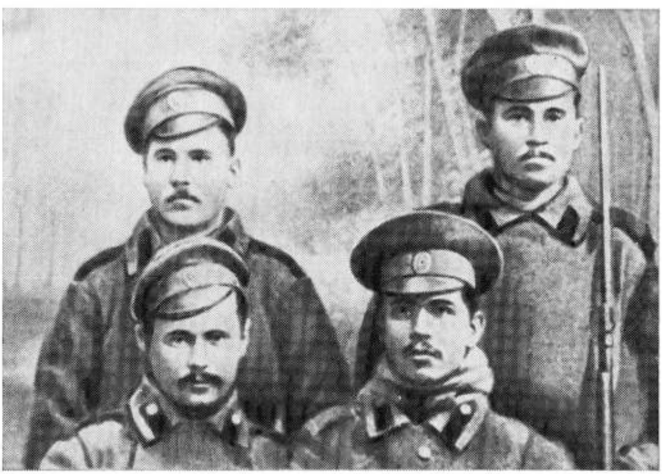
Moscow University Graduation Diploma.

Student at Moscow University, 1912.

Sergei Vavilov as a student with his Commercial School classmates, 1912-1913.



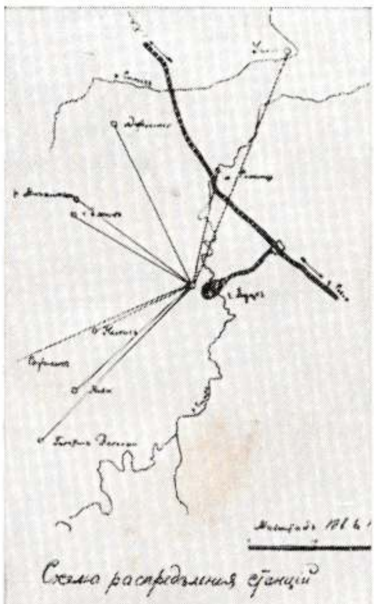
In Italy, 1913.



S. Vavilov (on the bottom right) with members of the field army, 1915.

Ensign S. Vavilov, 1916.

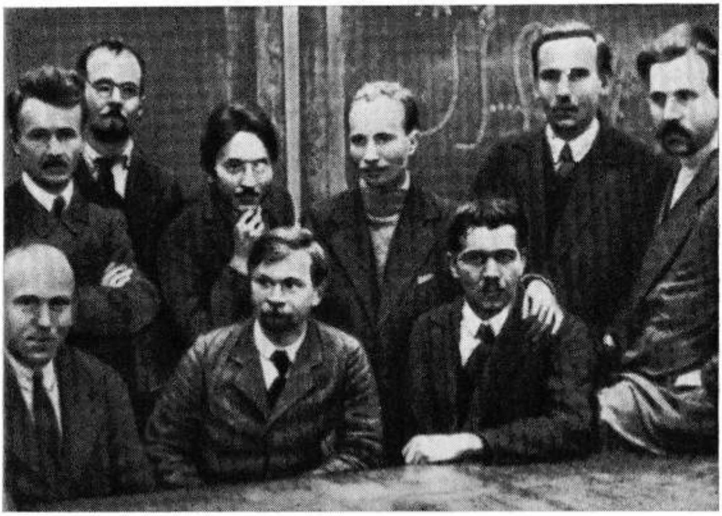
N. and S. Vavilovs with their mother at the time of S. Vavilov's short stay in Moscow while on leave from the front, 1916.



A diagram showing the location of radio stations in S. Vavilov's experiments at the front, October, 1916.

Olga Mikhailovna Vavilova (photo taken by S. Vavilov in the beginning of the twenties).

Viktor Sergeevich Vavilov, 1939.



A group of members of the Physics and Biophysics Institute. Bottom row: E. Shpolsky, P. Lazarev, S. Vavilov, and E. Sirotin. Top row: P. Shmakov, N. Fyodorov, T. Molodyi, A. Predvoditelev, and P. Belikov, 1924.

V. Levshin and S. Vavilov at the time of the 6th Congress of Russian physicists. August, 1928.

S. Vavilov with a group of students of the Department of Physics at Moscow University. Bottom row: V. Antonov-Romanovsky (first from the left), S. Vavilov (third from the left). Top row: I. Frank (first from the left), D. Blokhintsev (second from the left), M. Markov (fourth from the left), 1930.

A meeting of Soviet and French physicists. Bottom row: F. Joliot-Curie, A. Ioffe, and I. Joliot-Curie. Top row: D. Skobeltsin and S. Vavilov. September, 1936.

S. Vavilov as Head of scientific research at the State Optics Institute and the Lebedev Physical Institute of the USSR Academy of Sciences, 1941.

May 1926 came back home to Moscow. Before his departure he wrote to Levshin: 'I have so many plans of what we can do with gases and liquids.'

From Vavilov's letters one can readily imagine how strenuously his creative mind had been working while he was in Germany for nearly five months (his stay there had to be curtailed for purely financial reasons). One cannot but wonder at his fantastic ability to work, his purposefulness, and the talent to obtain maximum useful information within a short period of time and to implement his findings immediately in practice.

When he was in Germany, Vavilov thought of a plan for extensive research to be carried out in Moscow; he began to write the popular-science book *The Eye and the Sun*, developed a new course of lectures in 'Fluorescence and Phosphorescence', and did all he could to help the Institute of Physics and Biophysics with new equipment and literature.

On the money from his meagre allowance he bought various dyes produced at the German chemical plant 'Kolbaum'. For many years they served as objects for analyses at the luminescence laboratory of the Lebedev Physical Institute of the USSR Academy of Sciences. Suffice it to say that in the mid-sixties the author of the present book availed himself of the dyes that Vavilov had brought from Berlin as far back as 1926.

THE SCIENTIFIC SCHOOL

In the very first years after the Great October Socialist Revolution the higher educational institutes had, in the shortest possible period of time, to provide the country with technically educated specialists. That was why the administration of these schools was quite willing to hire those working at research institutes as lecturers. In the light of this extraordinary situation, holding more than one job was wholly encouraged. This resulted in that quite a few people from the research institutes worked at one, or sometimes even at several, higher educational institutions.

In 1918, at practically the same time that Vavilov began to work at the Institute of Physics and Biophysics, he started his pedagogical activity. His teacher Pyotr Petrovich Lazarev had already been employed (since

1912) as a part-time professor at the Moscow Higher Technical School, where he offered Vavilov a job in his department. Those were very hard times and the city's transportation system was functioning but poorly. Lazarev and Vavilov were obliged to regularly commute from Miusskaya Square to Lefortovo, which was located at the other end of Moscow. Vavilov assisted his professor at the lectures on physics and conducted the laboratory sessions. These sessions were rather primitive, and Vavilov decided to reorganize them completely: he assigned a number of new experiments and provided the necessary descriptions.

In several years' time Vavilov became professor of the Department of Physics and Theoretical Illumination Engineering at the Moscow Higher Technical School. Until 1927 he taught two courses and, at the same time, supervised students' graduation papers on illumination engineering. One paper should be mentioned in particular: it was on the use of the ultraviolet radiation of a mercury lamp to obtain visible light with the help of luminescent substances. This study gave rise to further research along the same lines, which was carried out under Vavilov's direction for many years, and led to the creation of luminescent lamps.

Since autumn 1920 Vavilov had also been teaching part-time at the Moscow Zootechnical Institute, which had been recently established on the basis of an agricultural middle school. The level on which physics was taught at the Institute was low and the physics laboratory was not very much different from the physics laboratories in secondary schools, which was quite inadequate to that in a higher educational institution. No one was paid to assist the lecturers and they had to prepare all the required demonstrations on their own.

When Vavilov became professor and head of the Physics Department at the Zootechnical Institute, he asked Levshin to join him. Working together they did much to enhance the level of the students' knowledge. Vavilov's letter to Levshin from Berlin reveals his opinion of the students: 'I was present three times at the examination of medical students (the examiner was Pringsheim himself). Their answers were approximately on the same level as the ones we hear at the Zootechnical Institute. The ineptitude is most strikingly similar.' Vavilov was very serious about his work at the Zootechnical Institute

and did all he could to improve the training of its graduates.

Of greatest significance was Vavilov's pedagogical activity in the Faculty of Physics and Mathematics at Moscow State University. In 1932 it was reorganized to become the Faculty of Physics. It must be mentioned that Vavilov was one of those who were indefatigably keen on seeing the Physics Faculty at Moscow State University acquire independent status.

Long before, shortly after his return from the army Vavilov, while teaching at the Moscow Higher Technical School, had also begun teaching at the University. At first he was a rank-and-file teacher; then he became a senior assistant-lecturer at the Physics Department, where he conducted classes in general physics. In spring 1919 he gave a trial lecture and passed three examinations for the Master's Degree (on experimental physics and physical chemistry), after which he was appointed assistant professor at the University and began to deliver his lectures for the students: first on photochemistry and later, on the absorption and dispersion of light. Vavilov's lecture courses were highly original in that they contained entirely new material derived from the scientific literature and were characterized by the author's own views on the subject.

In 1929 it was decided to organize the Department of General Physics in the Faculty of Physics and Mathematics of Moscow State University. Vavilov was offered to head the new department. Fully aware of how responsible the appointment was, he gave up his job at the Institute of Physics and Biophysics as well as the teaching position at the Zootechnical Institute, and devoted himself entirely to research and pedagogical activity at Moscow University.

This was the time when many young people with inadequate teaching experience were working at the University's Faculty of Physics and Mathematics. Hence it was first and foremost necessary to work out a uniform curriculum of courses and compile assignments for laboratory sessions and seminars. With the help of more experienced teachers, Vavilov prepared a syllabus covering the comprehensive course in physics. In 1931 it was discussed and approved at the scientific council of the Faculty.

In his report at that meeting Vavilov presented a sufficient amount of evidence in favour of the structure and content of the syllabus, which in its turn included a panorama of the latest achievements in physical sciences. From what the speaker said it was quite clear that his erudition in all the fields of physics was profound. The new curriculum was implemented beginning in September 1931. With amendments introduced now and then, it has been functioning as such for over forty years.

Vavilov paid great attention to the planning of seminars and to the physics laboratory sessions. Questions pertaining to teaching methods were discussed at the regularly held staff meetings. All types of classes in the general course of physics were conducted according to one and the same plan. Vavilov even worked out a questionnaire on the course in general physics for the members of the examination board.

In Vavilov's opinion any student who had completed the course in general physics and had likewise received experimental training in the physics practicum had to be prepared to teach on his own and possess adequate knowledge to cope with the functions of a junior scientific investigator at the laboratory of a research institute or in industry. The implementation of these serious demands called for a marked improvement of the level on which classes were conducted, the introduction of the most recent discoveries in physics, together with a significant improvement in the physics practicum by incorporating the latest achievements in experimental technology.

When Vavilov became head of the Department of General Physics at the University, he reorganized and considerably renovated the general physics practicum. He worked hard to compile a new compendium of laboratory assignments and designed a number of up-to-date demonstration instruments for the physics laboratory. In his courses of lectures Vavilov paid great attention to methodological problems, in particular to those that were connected with the relativity theory. In this respect, his book *Experimental Fundamentals of the Theory of Relativity*, which he wrote in 1928, was highly propitious. Vavilov's lectures were a great success. The students always barraged him with questions, and he was never in a hurry to leave the lecture room, remaining to discuss

things with his listeners for as long as it was required.

Taking into consideration the rapid development of special departments at the Physics Faculty, Vavilov initiated the organization of a number of specialized practicums in physics. This idea was enthusiastically supported by the members of the faculty. There was no stint on the part of the laboratories to provide such courses with all the necessary equipment. Thus, several such courses were introduced and were attended by students in the upper classes. This entirely new approach to the teaching of physics served as an example that was followed by many other universities in the country.

The idea to write a book of problem sets in physics that would meet the high demands of future specialists originated with Sergei Vavilov and Professor Vyacheslav Romanov. The authors of the future manual were selected and the basic principles underlying the book were elaborated. This was followed by the compilation of a great number of original problems.

Professor Ivan Yakovlev recalled that when in 1929 he entered the Faculty of Physics and Mathematics of Moscow State University, the course in general physics was no more than a dull experience, amounting to the mere rendering of the then widespread textbook on physics by E. Grimzel. Very soon the students, who were wholly dissatisfied with the lectures stopped attending them altogether.

Beginning in September 1930 the course in general physics (optics) was taught by Vavilov. Immediately, everything changed. Yakovlev considered those lectures to have been the best ones he had ever heard in his life as far as the profundity and novelty of the material were concerned. At the very first lecture Vavilov said that if the students wished to know the subject in the proper sense of the word, they should not confine themselves to lectures alone. He named a number of important books with which it was necessary to become acquainted. The lecture produced an enormous impression on all those present and the young people wasted no time in rolling up their sleeves to do some real work.

Vavilov conducted the seminar and lab sessions in the practicum. Assistant Professor Grigori Bendrikov used to say that the Professor knew every single problem in its minutest detail, followed the work of his students very

attentively, and never failed to give them the necessary instructions while the work was in progress. The students always prepared very diligently for those classes since it was hardly feasible to work otherwise under Vavilov's guidance.

In 1937, Moscow State University, following the example of many other educational institutions in the country, introduced the so-called 'brigade-method of teaching'. Lectures were abolished. All the undergraduates were divided into groups of five or six people. During the classes the brigades were seated in different parts of a large room and read their textbooks. The teacher was supposed to instruct such groups in succession. Introductory talks were held prior to such classes.

Vavilov did not approve of this method—incidentally, without justifying himself—and allotted more time to the explanations preceding these classes. There were even some teachers who blamed Sergei Vavilov for continuing to adhere to the old lecture system while conducting what was then called the preliminary talks.

Another novelty that Vavilov introduced was the writing of papers. He offered his students a choice of ten subjects on optics. During specially appointed hours the professor would ask his students to come to his office on the ground floor, where standing at his escritoire he would give a detailed analysis of their work, pointing out its merits and flaws.

Professor Anatoly Vlasov recalled that in 1929, when he was a third-year student, he was once present at a lecture on optics, which was given by Vavilov for the fourth-year students. Vlasov saw a tall, handsome man, one of the intelligentsia, whose manner was unrestrained, well-wishing, and yet dignified. The subject matter of what he spoke was abundantly clear and presented by him most consecutively. When the lecture was over, Sergei Vavilov was surrounded by the students who bombarded him with numerous questions. G. Bendrikov often spoke of how devoted the young people were to Vavilov. He was never carried away by the purely theoretical aspects of his subject and made every possible effort to explain the sum and substance of any particular phenomenon as clearly as was necessary, accompanying his lectures by demonstrations. Assistant Professor Elizaveta Chetverikova told the author of this book that the students

had once come up with the request that Sergei Vavilov, Aleksandr Predvoditelev and Sergei Konobeevsky—the three young lecturers who were the best in their opinion—should be made members of the scientific council. The authorities complied with the request.

From 1930 to 1932, Vavilov was chairman of the educational commission at the Faculty of Physics and Mathematics of Moscow University. The commission was plenipotentiary in that it carried out the functions of what is now called the dean's office together with those of the teaching methods commission. It dealt with problems concerning the syllabus, the requirements the undergraduates were supposed to meet in the proficiency tests and examinations, the selection of lecturers, and many other things. The commission included the most outstanding lecturers and the best representatives of the students. Their decisions were reached by secret voting. Vavilov always enjoyed prestige with the students who also confided in him in all respects.

Professor Nikolai Malov used to recall that the first time he had happened to meet Sergei Vavilov was when the latter was a young lecturer at Moscow University. It was actually at a meeting of the educational commission which, in his own words, seemed to be very much the same as a staff meeting and a meeting of the education and teaching methods council of the Faculty rolled into one. Some of the professors had a guarded attitude to what the students said, but Vavilov listened to the young people with unabated attention and never failed to regard their comments with an attitude of goodwill. When the students suggested something that in his opinion was inappropriate, he always most tactfully explained them exactly where they had gone wrong.

Vavilov did much to improve the staff of lecturers. He suggested that contacts be established between the faculty and the institutes and establishments where the students were acquiring practical experience and that a commission to help the failing students be organized.

His kindheartedness was always appreciated by his colleagues. E. Chetverikova said that the members of his department were devoted to him and, knowing that he was often ill, did everything to spare him. When Vavilov gave his lectures, he always found himself covered with a great amount of chalk, which gave his

colleagues the idea to have a special brush for him. His behaviour was unaffected with everyone, including those who cleaned the rooms. Among the latter was an old woman V. Tikhomirova, who was particularly kind to Vavilov. She called him 'dear', and would say 'Go, dear, there's someone who wants to see you.'

Vavilov had the remarkable gift of appeasing the conflicting parties, and was often asked to take on the functions of a judge when disputes were to be resolved. He liked to joke by calling himself 'the peace-maker-in-chief'.

In June 1931 the University's local newspaper *For Proletarian Cadres* published an article under the headline 'One of the Best', where it was said that Sergei Vavilov proved to be extremely proficient in his work with the second-year students and was himself disciplined beyond reproach; it also said that he took a most active part in the public and academic life of the group teaching methods, syllabi, cyclicity of studies, and the preparation for continuous industrial training. With his help, the second-year student physicists were among the first to adopt the laboratory method of instruction. In his capacity as a lecturer Vavilov consolidated this method and made every effort to make it effective by giving introductory talks and explaining the most difficult items, as well as providing the brigades with daily guidance and opportunely notifying those students who lagged behind their groups. The article went on to say that as representative of the production committee S. Vavilov spared no effort in studying the special subjects and syllabi, and in enhancing the general level of the work in progress.

In those days Professor Konstantin Belov studied in the group that was taught by Vavilov. He used to say that the students were delighted with their teacher. The students themselves organized a group meeting at which they came up with the suggestion that Vavilov should be honoured with the title of merited professor—the token of appreciation of one's work which had been introduced at that time. The administration supported the students' initiative, and in October 1931 the decision was made to award S. Vavilov this title.

The University's local newspaper printed his photograph and the article 'The first merited professor', in which it was said, 'Sergei Ivanovich Vavilov is the first

merited professor at the department of physics. In 1930 the second-year students of physics together with S. Vavilov signed a socialist competition agreement on the fulfilment of educational and industrial training plans. At that time new methods of teaching were only in the initial stages of their development, and Sergei Vavilov was the first, or one might even say the pioneer, in this field of activity and presented the best method of conducting classes—called laboratory and brigade study. Sergei Vavilov's method has gone down in history... and now it is being referred to as Vavilov's method. Comrade Vavilov did not confine himself to the fulfilment of the socialist agreement with his group. His work in the production conference of the department can also be regarded as an example to be emulated. A whole series of valuable suggestions, instructions, and clear-cut ways of achieving success in the educational and production indices can also be justly ascribed to Sergei Vavilov. During the summer months he did a lot of work connected with the organization of specialized and general practicums in physics. By the time classes were resumed, he had produced the best curriculum in physics. And at present he is busy writing four textbooks, which he has undertaken to publish by the beginning of 1932. At the rally of higher educational institutions comrade Vavilov was awarded the diploma of a merited professor, the prize of 200 roubles, and the privilege to go on a scientific mission abroad'.

Vavilov received the diploma and the money, but did not manage to complete the textbook. He was hindered by his election to the USSR Academy of Sciences and moved to Leningrad. For exactly the same reasons, he could not avail himself of the mission to go abroad.

What Vavilov did to promote the growth of Moscow University can hardly be overestimated. In particular, it was he who initiated the invitation to one of the most talented Soviet physicists Leonid Mandelshtam to come and work at the University in 1925, which resulted in that the latter's celebrated scientific school of optical and radio and physics studies was created in the Faculty of Physics and Mathematics.

It was not only the scientists of the Physics Faculty whom Vavilov had drawn to teaching. Prominent specialists from industry and branched scientific-research

institutes were also involved. Thus, lectures on applied problems in optics began to be delivered at the University by Professor Aleksei Ivanov, technical director of the Moscow plant for the production of electric lamps, Professor Sergei Maizel, head of the illumination engineering laboratory of the All-Union Institute of Electrical Engineering, Pyotr Timofeev, a researcher at the same Institute and future corresponding member of the USSR Academy of Sciences, and a number of others.

Vavilov considered it vitally important that a physicist working in the field of optics had a profound knowledge of electronics. For this reason the syllabus in optics included courses in electronics that were given by Professor Nikolai Kaptsov, Samson Gvozdover, and others.

The close links Vavilov established between the Physics Faculty and industrial enterprises as well as with the All-Union Institute of Electrical Engineering proved to be especially valuable. In the laboratories of the industrial plants and the Institute the students of physics undertook their practical work, which was extremely rewarding as far as their training was concerned.

Vavilov's teaching methods and his contacts with the students were described to the author of the present book by the Dean of the Physics Faculty of Moscow State University, Professor Vassili Furtsev. During the 1929-1930 school year he was a third-year student of the Physics and Mathematics Faculty of Moscow University. At this time Vavilov began his course of lectures in optics for the fourth-year students. Vavilov encouraged the junior-year students to attend his lectures. Besides Vassili Furtsev, among the other third-year students who attended Vavilov's lectures were the future Professors Anatoli Vlasov and Sergei Mandelshtam; those who were in the fourth year at that time included the future Corresponding Member of the USSR Academy of Sciences, Dmitri Blokhintsev and Academician Ilya Frank.

Vavilov demanded active participation of his students. He used to suggest topics for their research, special literature, and taught them how to give reports. V. Furtsev was assigned a report on the Huygens-Fresnel principle, for which purpose Vavilov brought him from his personal library the book *Optics* by Paul Carl Ludwig Drude, which was written in German. Furtsev told Vavilov that he did not know German to which Vavilov replied,

'Well, then, this must be a wonderful opportunity for you to start learning it. Take a dictionary and translate it.' The student put in an enormous amount of work, and finally managed to translate the required chapter. Since then his mastery of the language showed definite signs of progress. The report he gave was a success. It should also be mentioned that every single report given by a student was amply commented on by Vavilov himself.

A similar case was recalled by another one of Vavilov's postgraduates, the present Academician of the Kazakh SSR Academy of Sciences, Nikolai Dobrotin. He had to become acquainted with the experiments carried out with the Wilson cloud chamber. On Vavilov's advice he was to thoroughly study the paper by the French physicist Pierre Victor Angier. When he finally managed to find the paper, he became very discouraged since he knew no French at all. He felt embarrassed and went to see Vavilov with the hope that his scientific adviser would recommend some other article either in German or at least in English. This, however, was not the case. Vavilov was adamant. Dobrotin had to borrow a dictionary and look up every single word. The professor was not in the least concerned as to how time-consuming the work would be. 'Do the translation entirely on your own, even if it takes you twenty-four hours to cope with a single page. If you persevere, it will become easier.' Dobrotin remembered this lesson for the rest of his life. Another instance that he could not forget occurred one day in winter when he met Vavilov in the street: the latter became anxious and told him that he was not dressed warm enough for such cold weather.

These reminiscences are supplemented by those of Anatoli Vlasov, who told the author of this book that in 1930 he found himself in the newly organized group of advanced students who were supposed to prepare themselves for their future scientific and pedagogical work in the higher school. Vlasov was to come and see Vavilov. The discussion concerned the attitude of the students of senior years to some of the concrete problems in physics and mathematics. Vavilov noted that according to his observations the students' interests were highly significant since in a large number of cases they were exactly what determined the fate of each individual. At the end of the talk Vavilov gave the young man instructions that

sounded most unambiguous: '... You must be in command of at least one foreign language in order that you could read and study the literature on physics and mathematics. Otherwise all that nature has endowed you with will be impeded in its development'.

In 1931 Sergei Vavilov delivered the general course in physics at the University and at the same time instructed some of the advanced students, thus preparing them for work as lecturers. Sometimes, instead of Vavilov the lectures were given by these students, though invariably in his presence (each one of them had to lecture on one or two occasions). A. Vlasov recalls in particular the following advice given by Vavilov: 'The lecturer ought to be interested, and even inspired, by the theme itself, and this can be encouraged by his own contribution to the subject matter that he is reported on, no matter how infinitesimal and confined to methods alone it might be. Given such an approach, he is able to make the lecture lively and elegant.'

Professor V. Furtsev recalled how Vavilov took him on as a diploma student. Vavilov recorded the research topics of the members of the department and postgraduates in a thick black notebook, which he always had with him and opened each time a certain question cropped up.

As has already been mentioned, Vavilov began delivering his course in general physics in the 1931-32 school year. He chose assistants for himself from among the postgraduates in the faculty who, working part-time, helped him to prepare the demonstrations used in the lectures and conduct seminars. Among them were the future professors Vassili Furtsev, Anatoli Vlasov, Sergei Strelkov, as well as two of the older colleagues—Maxim Divilkovsky and Mikhail Filippov (who were later killed at the front in the years of the Great Patriotic War).

Before classes Vavilov used to gather his younger colleagues to discuss some of the most interesting problems in physics, many of which he thought up himself. Each of his assistants had to give a trial lecture, which was assigned for in advance to allow for thorough preparation. Vavilov demanded that each of the lecturers submit a written account of what he planned to speak on, and this was subsequently discussed in great detail (including the lecture demonstrations, drawings, etc.). Vavilov was always present at these lectures together with his other

assistants. The lecture was then subjected to meticulous analysis that was never other than well-wishing.

Vavilov spared no effort to promote cooperation among scientists in all its possible forms. He encouraged the organization of scientific seminars and colloquiums in which he himself took an active part, and always asked his students and the younger colleagues to attend them too. By participating in scientific discussions the young people received excellent training and became accustomed to independent thinking.

In August 1928 the Sixth Congress of Russian Physicists was held. More than four hundred delegates took part in it. Among them were scientists from Germany, Great Britain, the USA, France, the Netherlands, Poland, and Czechoslovakia. They included Max Born, Leon Brillouin, Peter Joseph Wilhelm Debye, Paul Adrien Maurice Dirac, Gilbert Newton Lewis, Robert Richard Paul, Peter Pringsheim and other eminent physicists.

Academician Abram Ioffe, the Chairman of the Russian Association of Physicists, had planned the sessions of the Congress were to be held not only in Moscow, but also in the largest university towns situated on the banks of the Volga River, where the participants were expected to arrive by boat. The Congress was inaugurated at the Moscow House of Scientists. After four days of work in the capital the delegates went by train to Nizhni Novgorod (now called Gorky), and further by boat to Tsaritsin (now known as Volgograd), and then to Kazan and Saratov. At Saratov University the Congress concluded its work.

The Congress was a great success. Over two hundred reports were given; those who took part in the Congress became acquainted with the scientific laboratories not only in Moscow, but also in the three most prominent universities of the Volga River region. The meetings of the Congress were attended by a large number of researchers, teachers, and students, and the participants gave lectures that were comprehensible to the general public. The Congress itself became an outstanding event in the history of science, and served to stimulate new research in the field of physics.

Sergei Vavilov was appointed secretary of the organization committee of the Congress. He spared no effort to

see to it that the Congress be provided with everything that was essential to its success. At the Congress he gave two reports himself: 'On the possible limitations in the application of the optical principle of superposition' and 'Concerning the theory of fluorescence quenching' (this was prepared in collaboration with M. Leontovich).

At a later date Vavilov wrote: 'As was suggested by Academician A. Ioffe, it was decided that the new Sixth Congress be held on the Volga so that part of it could be conducted aboard the ship. Many people found this decision to be unreal as well as impracticable. But now the idea of a "floating congress" has become clear to all the participants and has turned out to be feasible and successful. Aboard the ship—in common cabins and on deck—talks and discussions on the most problematic aspects of present-day physics were held in a relaxed and free atmosphere. In several days' time the delegates managed to iron out all their differences; plans for conducting joint research were made, and physicists from different parts of the world had fully availed themselves of the opportunity to become acquainted as best as was possible.'

As time passed, many of Vavilov's pupils became eminent scientists themselves, while others were at the forefront of entire trends in the Soviet physical sciences, but the feeling of profound gratitude to their teacher never deserted them, and the memory of his is still kindling in their hearts.

Thus, Academician M. Markov wrote: 'Portraits, sculptures, and even photographs simplify rather than give an adequate impression of Sergei Ivanovich Vavilov's multilateral personality. What they all lack is the Vavilov charm, which belonged to Sergei Ivanovich alone. They are but mute effigies of the man whose large, brown eyes are deprived of their warmth and the magic power to pierce through your mind and heart. They fail to echo his low voice, his cough, to make you hear his humour, to see his gestures when, removing cigarettes from his pocket, he seemed to draw you to himself with his penetrating look.'

Sergei Vavilov's achievements in various fields of physical optics were such that he had every right to say, 'Light itself is my calling.' And wherever he worked, he always attracted young people, and directed any

newly organized young body of researchers who worked under his scientific guidance with no stint of enthusiasm.

Vavilov was particularly keen on training specialists in the field of luminescence. It was from scratch that he organized the Soviet school in luminescence studies. He attracted many researchers to the field: Vadim Levshin (from the Physics and Biophysics Institute); Evgeni Brumberg, Boris Sveshnikov, Ilya Frank, and Aleksandr Shishlovsky (from the Physics Faculty of Moscow State University); Aleksei Bonch-Bruevich, Viktor Zelinsky, Anton Sevchenko, Tatyana Timofeeva, Nikita Tolstoi, Pyotr Feofilov, and Ivan Khvostikov (from the State Optics Institute); Emmanuil Adirovich, Mikhail Alentsev, Mikhail Galanin, Maria Konstantinova-Shlezinger, Pavel Cherenkov (from the Lebedev Physical Institute of the USSR Academy of Sciences); and many others.

Vavilov's school quickly expanded. His followers successfully conducted their research, became ever more experienced and acquired their own pupils, who by right can be considered to be Sergei Vavilov's scientific grand- and even great-grandchildren. Even in Vavilov's time, his school had become one of the most prominent scientific schools in the country, while its range and the profundity of the research carried out in luminescence studies had given it every reason to be regarded as one having world significance.

Sergei Vavilov did not like to reveal what troubled him. His expression was practically always calm, revealing, as it were, neither joy nor grief. As a person he was extremely self-possessed, and never failed to remain even-tempered and congenial to his students who, in his opinion, shared exactly the same rights with him. His relations with the younger members of the department were always somehow unconstrained. The young researchers were never inhibited to share their ideas with him, and were not afraid their suggestions would be laughed at.

Vavilov was averse to large scale laboratories. He deemed it sufficient for a laboratory to have a staff of not more than ten or fifteen people. When visiting the laboratories his numerous commitments did not prevent him from having discussions with each researcher for as long as was required, sharing his own experience and ideas, and always being willing to give advice. The remarkable physicist first and foremost aimed at simplifying the exper-

iment. He had the wonderful gift of solving the most difficult problems by using methods that were both simple and ingenious.

Professor N. Tolstoy wrote that Sergei Vavilov had no minor managerial talent when it was necessary to organize the work of individuals, small and large laboratories, and institutes (irrespective of their number), adopting in each case a unique approach. If the person working under him proved to possess an inventive mind and could find his own way to the solution of the problem, then Vavilov would set a broad and general goal. However, if the associate was either a beginner, or someone lacking in initiative, then Vavilov would suggest part of an experiment, explaining all the minutest details.

When he had to deal with one of those regularly submitted 'projects' he would usually subject it to criticism. He would explain who, when and where, over the past thirty or forty years, had been tackling the very same problems, and why nothing had come of it then and was unlikely to become feasible now, and he would advise that it be done differently. Three quarters of such "projects' were rejected after Vavilov's criticism. But in those cases when the young researcher was obstinate and began to implement what he thought was right, Vavilov would never avail himself of the rights of a boss and would patiently await the outcome, which was either in his favour (in most cases), or in favour of his colleague (less often). In the latter cases, Vavilov never exhibited any displeasure; he would be rather quite happy, and would do everything he could to help the work be successfully accomplished.

In the initial stage of the research, Vavilov used to tell his students to employ the simplest possible models so as to get to the bottom of the physical phenomenon under investigation. In his opinion, it was only after the general outlines of the phenomenon were made clear that the research could be handed over to the theoreticians so that they could 'do everything that was required'.

Throughout his life Vavilov worked selflessly and devoted himself entirely to science. He demanded exactly the same devotion to work of his own pupils. When he saw that someone had a purely formal attitude to what he did, he lost any interest in this person. He was highly displeased if one of his colleagues showed no initiative,

but blindfoldedly followed the instructions, even if they came from Vavilov himself. In cases like these the professor would say: 'You work as if you were a clerk rather than a researcher!' If any one of his pupils, on finding himself confronted with difficulties, was at a loss and did not know what to do next, Vavilov encouraged him by saying, 'Don't behave as if you had nothing to do!'.

Vavilov always entered the laboratory with one and the same question, 'Well, and what do you have to tell me this morning?' The question was not a mere conventionality: it always reflected his genuine interest in what was going on. His student M. Galanin, who is now a Corresponding Member of the USSR Academy of Sciences, used to say that Vavilov's lively interest always encouraged the young people who continuously found themselves ever more cognizant of how significant their own work was. Meanwhile in this regular question there was also the implication of an unambiguous demand: the staff members were obliged to give a detailed and substantial account of what had actually been done over the past period. Vavilov had a remarkable memory and was very displeased when people tried to tell him one and the same thing several times. He was interested only in what was entirely new.

N. Tolstoy recalled that Vavilov never praised his students in their presence. It was only indirectly that they found out with what warmth he spoke of them and how proud he was of their attainments. I. Frank wrote that in 1929, when he was a student of physics at Moscow State University, he was sent for practical training to the State Optics Institute in Leningrad. His teacher Vavilov said, 'Try to work under Terenin,' and he gave Frank a very complimentary letter of recommendation.

As a rule, Vavilov was generous about writing recommendation letters. He wrote them with pleasure, refusing to do so only in rare cases. However, as A. Mints used to say, in spite of his benevolence, magnanimity, and kindness, Vavilov could hardly have been said to go to extremes. In fact, he was merciless to those who proved to be undisciplined, lackadaisical and dishonest.

From I. Frank's reminiscences we learn of the case when one of Vavilov's laboratory assistants, who was taking measurements, was caught falsifying results. Vavilov dismissed him from the Institute immediately

and explained that his unequivocal decision had been motivated by his conviction that science as such rested entirely upon trust and that a person practicing deception could never be believed again.

Sergei Vavilov's high demands at the seminars were common knowledge. P. Feofilov wrote that he occasionally happened to witness how Vavilov showed no pity to those speakers whose immature reports contained rather dubious results. His criticism, though harsh, was invariably objective and well-wishing in the end. What Vavilov was primarily guided by was his wish to help the person find his place in science and in life. His extremely high demands went hand in hand with tact and the understanding of what could actually be expected of a particular individual. He used to say: 'Each one does as much as he can.' G. Faerman recalled that Vavilov's attitude to any member of the staff was primarily conditioned not so much by how much the person had done, but by whether the person had worked to the fullest of his abilities.

Vavilov showed great concern for those whose perseverance in their work had won his esteem. A. Vlasov told the author of this book how he and V. Fursov, who had once been Sergei Vavilov's students, happened to run into him at the end of the war. Vavilov was unimaginably glad that both of them had survived the years of hardships brought about by the war. In their conversation he particularly stressed the fact that physicists would be faced with highly important tasks in the post-war period. When they parted with their teacher, Fursov said to Vlasov: 'Sergei Vavilov greeted us as a father.'

Vavilov was proud of the results achieved by his students even when they began to work in fields remote from what interested them before. Professor A. Vlasov said that soon after the war the famous German theoretician M. Born came to Moscow. On this occasion Vavilov invited a number of people from other institutes to the Lebedev Physical Institute, USSR Academy of Sciences. One of them was Vlasov. Vavilov asked his former pupil to give Born an offprint of his paper on the theory of solids, of which he himself had a very high opinion. The theory that was expounded there was different from what was being developed by Born.

With a great pride, Vavilov introduced Vlasov to Max

Born. Vlasov gave Born his article and Vavilov forthwith read its opening words: 'In Max Born's theory of solids the very fact of the periodic structure of crystals is postulated rather than derived...' Born thought a little and said that he would comment on this statement later. Soon he published his article on the theory of crystals, in which Vlasov's work received the credit it deserved.

P. Feofilov used to say that knowing perfectly how to organize his own work (otherwise it would have hardly been feasible to accomplish as much as he did!), Vavilov was genuinely surprised when he found out that a researcher had failed to do what was required of him, being as it were, pressed for time. 'And how do I manage to cope with everything? Aren't I much busier than you are?' he used to say on such occasions. Vavilov was highly displeased when, for instance, articles were not submitted in time, or dissertations were delayed. 'Am I supposed to pave your own way for you?' he would say.

Those who worked with Vavilov still remember how he could be singled out amongst the people entering the building at exactly nine o'clock in the morning. He considered it *infra dignitatem* to have his health, age, or position interfere with his meticulous punctuality. It is impossible to recall a single instance when he was responsible for some delay in the beginning of a seminar or the opening of a conference.

Vavilov paid great attention to the planning of the scientific projects of his researchers. He regarded the absence of a clear-cut plan of scientific research, even given strict discipline and a strong wish to follow the plan, as something serving to markedly impede the progress of the undertaken research.

As a highly cultured person himself, Vavilov never failed to appreciate the same quality in others. Regarding V.I. Lenin as a supreme paragon of a scientist and a human being he laid particular stress on the fact that 'V.I. Lenin was a Russian intellectual in the broadest and best sense of the word.' Vavilov was convinced that he could do much more by setting a good example for his associates than by lecturing them. I. Frank wrote that over the many years of his contact with Vavilov he had never heard him say anything frivolous, to say nothing of using unconventional expressions that, unfortunately, some of the scientists considered to be 'vogue words'.

Sergei Vavilov could be called a genuinely cultivated person in the meaning of the words used by the great Russian writer Anton Chekhov. Thus, Valentina Shchaenko, a researcher at the Lebedev Physical Institute of the USSR Academy of Sciences, told the author of this book that when wishing to enter the laboratory, Vavilov always knocked on the door and never opened it until he was asked to come in. On entering the room he never took his chair without first making sure that his back was not facing anyone of those present.

I. Frank recalled that each time Vavilov could spare half an hour or so, he would come to the laboratory and have a quiet talk with his colleagues. Those were periods of relaxation, but they were never filled with idle chatter. The conversations that took place were exceptionally instructive and interesting. Vavilov, whose knowledge of Latin was brilliant, used to occasionally intersperse his speech with Latin apophthegms that could not have been more opportune in each particular case.

Vavilov was a coruscant representative of P. Lebedev's school of science. He had inherited the best tradition of this wonderful body of researchers, one of whose mottos was 'A true intellectual does not shrink from any kind of work.' Academician P. Rebinder, who was Vavilov's colleague at the Physics and Biophysics Institute, wrote in his reminiscences of the first years of their cooperation that in those days even the fully fledged scientists did everything 'with their own hands', without the help of either other researchers or laboratory assistants. One could often meet Vavilov in a workshop where he would be turning some required parts for an instrument on a lathe. He retained the lifelong conviction that young scientific researchers should conduct all the necessary preparations for the experiments as well as the experiments themselves entirely on their own. He adhered to the principle that a person should learn quite a lot himself before starting to guide the work of others.

During Vavilov's youth any experimenter working in the field of optics had rather meagre facilities to content himself with. No scientific endeavour had been attained without a great deal of strenuous work. Recollecting his very first experiments, Vavilov wrote that they had been 'extremely enervating'.

As far as the manner of conducting research was con-

cerned, Vavilov had in many ways followed the methods of his teacher Lebedev. Prior to each experiment he always thought over the minutest details, attempting, as has already been mentioned, to achieve the desired aim by employing relatively simple means. The results thus attained were further subjected to thorough discussion. It was those precise skills that Vavilov tried to teach his own students. In spite of the fact that as early as the thirties he had too many commitments to allow him to work 'with his own hands', he did not lose the ability to subtlety and profoundly feel and love experimentation till the very end of his life.

Vavilov pointed out that the elaboration of new instruments and methods should, by no means, be an aim in itself. What should be most important for the experimentator are the scientific results that could be obtained with the help of the developed methods. The case in point can be illustrated by what the author of the present book heard from Professor B. Neporent. When the latter was a postgraduate, he was one of the first at the State Optics Institute who took up the photoelectric registration of light and designed a photoelectrical spectrophotometer. In those days it was customary for postgraduates to discuss their work at meetings of the scientific council. Neporent, proud of what he himself had constructed, was uninhibitedly giving an account of what he had done when all of a sudden Vavilov said, 'What you are telling us is only the gravy, and may I ask where the meat is?' Vavilov was satisfied only when he heard that Neporent had not merely worked on the instrument, but had actually been able to take interesting measurements with it.

Vavilov was averse to frequent and immature publications. In his opinion the young researcher should produce one, or at maximum, two, articles a year. Each work, however, must have been properly thought through, the experimental results irrefutable, and their disquisition and conclusions substantiated. At the same time he could not suffer anyone whose reluctant attitude to work did not bring any tangible results for a long time. In cases like these he used to say: 'Remember, that time forever envious is on the run.' Professor M. Konstantinova-Shlezinger told the author of this book that when she received the topic of her research from Vavilov in 1926, she wasted no time in beginning to read on the

subject as thoroughly as possible. Very soon Vavilov got interested in how she was progressing with her work and became very displeased that she had not yet started carrying out the experiment. He said that, at the rate at which she was working she would not even accomplish the preliminary work by the age of sixty and would thus not contribute anything to science.

Vavilov always encouraged the beginners, and did all he could to assure them of their own abilities. The author of the present book has every reason to say this of himself. In 1949, when I was in my last year at the Physics Faculty of Moscow State University, I was to do my graduation paper at the luminescence laboratory of the Lebedev Physical Institute of the USSR Academy of Sciences under M. Galanin, a Candidate of Sciences who is now a Corresponding Member of the Academy. The topic of my diploma paper was suggested by Vavilov himself. It concerned an experimental verification of one of the conclusions resulting from his theory of concentration effects.

The work was accomplished and the disquisition of its results was being prepared for publication. However, there was a rigid rule that Vavilov had introduced at that Institute, which is complied with up to this very day, viz. that the author of each new work has to give a report on it at the weekly colloquium of the luminescence laboratory, and that it can be published only after it has been endorsed.

I had regularly attended that colloquium and had had ample opportunity to see for myself how every single paper was discussed and its minutest details subjected to heavy criticism. Suffice it to say then that I had been on tenterhooks before my turn came to face the ordeal. I was really frightened to take the floor for the first time in my life before this kind of audience with Vavilov himself among those present.

The seminar was held in the conference hall of the Lebedev Physical Institute in Miusskaya Square. Vavilov took his seat in the front row. I was so nervous that I began saying something that could not have possibly sounded coherent: I was looking at Vavilov all the time and was hopelessly losing the thread of everything that I had so assiduously prepared to say. Vavilov, who had presumably understood how excited I was, encouraged

me now and then with either a kind word or a friendly nod. Thus I was able to regain my composure and managed to reach the end of my report and even give satisfactory answers to the questions that followed it.

In the concluding remarks Vavilov expressed his approval of the results that I had achieved and, as was usual with him, gave a number of new recommendations. The support that I received from Vavilov encouraged me, made me feel more confident of myself, and my gratitude to him for that day will remain in my heart forever.

Bertold Neporent recalled how in 1937 he was taking his examinations to become a postgraduate. The examination commission included Sergei Vavilov, Torichan Kravets, Aleksandr Tudorovsky, and other leading scientists of the State Optics Institute. During the examination Vavilov rose, asked Neporent to take his seat, and began pacing the room and asking him questions. His well-wishing attitude immediately created a genuinely friendly atmosphere. What he demanded of an examinee was not what the latter had crammed into his head, but the ability to think on one's own. It was the first time that Neporent had felt how pleasant it was to deal with people who were both more experienced and friendly to their colleagues.

Vavilov's kindness was felt not only by the younger researchers but also by the senior members of the staff. The following episode remains in my memory. I was working on my graduation paper in Galanin's room, who had not long before designed a phase fluorometer, an instrument that was then regarded as universal and intended for measuring the duration of time spent by molecules in an excited state. The instrument was cumbersome, the radio engineering part of it was rather complicated, and some of the units were still to be perfected. That was why the instrument was very often out of order.

Vavilov visited the laboratory once a week. Everything would be carefully prepared for his arrival since we had thoroughly wanted to show him the fluorometer in action. But as ill luck would have it the instrument would fail to function either on the eve of his visit or in his presence. This used to cause general frustration, but the only person who never expressed any dissatisfaction was Vavilov himself. He amiably joked about it attributing

the breakdown of the fluorometer to what he called the 'visitor-effect'.

Vavilov was extremely particular when questions of coauthorship cropped up. This was the case with the work of P. Cherenkov, and of E. Brumberg, who at that time was only a laboratory assistant. In spite of this fact, Vavilov, whose contribution to the investigation was enormous, insisted on Brumberg's name coming before his own, as was in accordance with the alphabetic order.

Academician S. Vernov told the author of this book that when he began the course of studies for the doctoral degree at the Lebedev Physical Institute of the USSR Academy of Sciences, as a permanent resident of Leningrad, he could not get any accommodation in Moscow and had to remain in his hometown. He was supposed to receive his grant in Moscow where he could not go often, and for several months received no money at all, being obliged to live on the means provided by his parents. Vavilov then asked Vernov to come and see him, and insisted on being given the power of attorney to receive Vernov's allowance for him. He regularly did this when he was in Moscow until Vernov moved to the capital himself.

In 1936 Vavilov asked the future Academician V. Veksler to come to work at the Lebedev Physical Institute of the USSR Academy of Sciences. Veksler recalled that the first thing Vavilov had taken care of was to see to it that Veksler would not suffer materially from the transfer to a new job.

It has already been mentioned that Vavilov was meticulously punctual and had never been late for meetings; neither had he ever cancelled any appointments. However, on one occasion his rigid rule was violated. N. Smirnova, one of Vavilov's assistants, described this event as follows: 'I remember that it was a cold, rainy day in autumn. We were expecting Sergei Ivanovich to come, as was usual with him, at one o'clock in the afternoon. But Sergei Ivanovich had not yet arrived. There were some people who wanted to see him in the waiting room. We were becoming more and more worried... When he did appear he explained that he had been detained because of the funeral of one of the staff members of the Physics Faculty of Moscow University who had worked

in the physics laboratory for forty years.* 'I have known him for so long,' Sergei Ivanovich said, 'How could I possibly not attend his funeral?' He was wearing a very thin coat and no galoshes.'

Sergei Usagin, one of the oldest assistants who helped with the lecture demonstrations at the Physics Faculty of Moscow University, told the author of this book about Vavilov's exceptionally responsive nature. Soon after the war his wife fell very seriously ill. When she left the hospital, it was recommended that she recuperate in a specialized sanatorium. This raised a number of problems and Usagin decided to ask Vavilov for help. Vavilov met him very cordially, rose from his seat to greet him, offered him the armchair, and gave him his full attention. He immediately ordered that Usagin's wife be given a place in the sanatorium belonging to the USSR Academy of Sciences. Thirty years later S. Usagin spoke of this with tears of gratitude in his eyes.

It would not be out of place to mention here again that Vavilov was invariably polite with absolutely everyone, irrespective of his or her rank. He always addressed people using their first name and patronymic, which is the conventional civil form of addressing people in Russian. The only exception he made was in the case of the Institute's mechanic Aleksandr Rogovtsev who had known Vavilov ever since the latter was a student, had worked with him all his life, and was thus averse to any forms of address that were merely in compliance with what was considered to be socially correct. Vavilov amiably called him 'Mikhalych' (the contracted form of this man's patronymic).

I can still clearly remember how Vavilov addressed the USSR Minister of Health with a request to obtain some medicine that was not easily available and that was urgently required for L. Levshin's brother, who was at the time very seriously ill. On another occasion Vavilov decided on his own to telephone the Minister of Communications of the USSR and succeeded in getting permission to have a telephone installed in Levshin's flat, of which he had been deprived during the war.

M. Galanin told the author of this book that when he came back from the front, he was given a job at an in-

* The deceased was Vladimir Volodkin, who had been responsible for providing lectures with demonstration facilities.

stitute that dealt with problems that were quite remote from his own interests. Vavilov had known Galanin since the prewar period when the latter worked as a laboratory assistant at the Lebedev Physical Institute of the USSR Academy of Sciences. Vavilov lost no time in getting in touch with all those who could actually obtain permission for Galanin to return to his institute where he began conducting research in the field of luminescence studies.

V. Veskler's reminiscences reveal that there were quite a few people to whom Vavilov rendered material assistance from his own means. He managed to do this without offending anyone, and in most cases made every effort not to let the person know from whom the financial support had come. N. Smirnova recalled that Vavilov never forgot about two persons whom he used to call 'my soldiers' and with whom he had served at the front during the First World War. He helped them with money and wrote them regularly, always writing the letters in his own hand, without relying on either his secretary or the typist.

Everyone who came in contact with Vavilov can remember his kindness. Academician I. Frank wrote: 'It is difficult to say why everyone who had the opportunity to associate with Sergei Ivanovich always had the feeling that he could depend on Vavilov. For some reason or other one never felt inhibited to approach him when a problem cropped up or when one had any kind of personal request. I am sure that not only I, but many other people, years and decades after Sergei Ivanovich had passed away, have shared exactly the same thought in moments of predicament. "Oh, how I wish I could have Sergei Ivanovich's advice!" '

Every single morning at the Lebedev Physical Institute of the USSR Academy of Sciences began in exactly the same way: the gate was unlocked, and at precisely the same time every day, a black 'Zis-110' car with Vavilov inside appeared. His study was on the fourth (top) floor. Although the building was limited to four storeys, it was nevertheless very high, and had no lift. During the last years of his life, Vavilov, who suffered from a weak heart, found it difficult to climb all the way up the stairs.

On the ground floor Vavilov was met by A. Rogovtsev,

who carried his bag (always filled with books and magazines) to his study. By the time Vavilov would arrive one of the researchers (most often M. Alentsev) would already be on the staircase landing of the second floor so as not to miss him and to ask him to drop in at the laboratory for just one minute on some business that was sometimes made up only to give Vavilov a brief respite. It is difficult to surmise whether Vavilov was aware of these little ingenuities on the part of his colleagues, which were but an expression of their guileless devotion to him.

In the days when Vavilov still worked at the Physics and Biophysics Institute he organized a seminar in optics, which soon became the centre of such studies in Moscow. M. Konstantinova-Shlezinger regularly attended this seminar, and recalled that Vavilov always came early so as to look through the latest periodicals before the others arrived. At those sessions he would usually discuss what was most interesting in the publications. However, if he didn't consider a certain work to be authentic, he would call it 'a fantastic tale'.

A large number of highly significant optical studies were discussed at the seminars. Thus, S. Landsberg said that in the beginning of 1928, L. Mandelshtam and he had obtained the first results relating to the Raman scattering of light: He made the first public announcement of this at Vavilov's seminar. Vavilov found the report very interesting and expressed his most favourable assessment of it.

Since the inception of the luminescence laboratory at the Lebedev Physical Institute of the USSR Academy of Sciences, a weekly seminar in luminescence studies was held. At first, those taking part in it included only the members of the Institute itself; they were later joined by people from other research institutes and educational establishments in Moscow as well as from different parts of the country. In due course the seminar had acquired national significance.

Even when Vavilov became President of the USSR Academy of Sciences he never missed a single seminar and demanded that his assistants see to it that its meetings were held according to schedule. The sessions took place every Wednesday at ten thirty in the morning. The agenda comprised reports on the results of original research, review papers, and other kinds of communica-

tions. Vavilov frequently took the floor, and each time his listeners were deeply impressed by his erudition, extraordinary memory, wonderful knowledge of the state of the art, and profound understanding of the sum and substance of the problems under discussion. Vavilov himself was most displeased when those who were giving their reports could not tear themselves away from the printed page. Jokingly he called them 'the page gazers'.

As he was personally acquainted with many foreign scientists, Vavilov often included in his lectures a large number of interesting facts about them that were known only to himself. This made what he had to say extremely lively, and the listeners were thus brought into contact with the history of science through an original source and obtained information that one could not derive from any literary source. N. Tolstoy wrote that what impressed people so much was Vavilov's gift of summarizing what he and others had said. He did this clearly and vividly, always presenting everything in perspective.

One would not err in saying that the organization and functioning of the all-Union conferences in luminescence were the result of Vavilov's own efforts.He attached great importance to them since they helped to coordinate the national research in this highly significant branch of science and promoted its further development. Four years after the first of such conferences was held in Moscow in 1944, the second all-Union conference in luminescence and the use of phosphors took place, which exemplified the rapid growth of research in this particular domain of science. Since then conferences in luminescence have become a regular event. They are held annually in different cities of the USSR and draw hundreds of participants. Thus, what Vavilov sowed had been yielding a fecund harvest.

In 1948 on Vavilov's initiative a monthly joint seminar of the Physics Faculty of Moscow University and the Lebedev Physical Institute of the USSR Academy of Sciences was organized. He himself was the seminar's most active participant. One could even go so far as to say that he was its heart and soul. He regularly presided at these meetings and gave several very important reports.

At that time I was a student of the Physics Faculty, and it was with no small interest that I attended the meetings

of this seminar, which took place in the grand physics lecture-room in the Physics Faculty's old building in Mokhovaya Street (in the centre of Moscow). The reports were usually followed by very lively discussions. Vavilov was very particular that the reports from the Physics Institute and the Faculty of Physics were presented in alternating order.

The seminars were attended by physicists from all over Moscow and quite a few students. The atmosphere at the sessions was perfectly unreserved. When Vavilov himself spoke, the audience was particularly large. Academician B. Vvedensky, recollecting the infallible success of Vavilov's reports, wrote that what underlay them was Vavilov's very special sense of humour, which was neither ponderous nor intended to produce any ostentatious effect. It was tangible in his intonation, gestures and pauses; while at times it was most coruscantly expressed in what proved to be a quite unexpected contrast, comparison, or accurate remark.

A report that remained indelible on my memory was the one in which he spoke on his theory of concentration effects in the solutions. The hall that held three hundred and fifty people was absolutely packed; many of those who were present had to stand for want of any vacant seats. I found everything Vavilov said so captivating that I decided to try my talents in this field of studies. In the years that followed I for a long time, actually occupied myself with the research on those highly complicated, and yet fascinatingly absorbing, phenomena, which Vavilov had told us about then.

The seminars did much to bring together the scientists of the two main physical institutions of Moscow; they promoted the establishing of contacts between them and the carrying out of joint research projects.

In the Physics Faculty building of Moscow University in Lenin Hills side by side with the statues of the most prominent Russian physicists A. Stoletov, P. Lebedev, and N. Umov there stands a sculpture of Sergei Vavilov: a white marble portrait by Vladimir Tsigal. It thus serves as a token of great esteem with which the Physics Faculty honours the memory of the outstanding Soviet scientist.

A GIFT FOR ORGANIZING...

In 1931 Sergei Vavilov's great services received his country's acknowledgement: he was elected Corresponding Member of the USSR Academy of Sciences, and a year later he became Full Member. For this reason, as was already mentioned, Vavilov left Moscow University and moved to Leningrad.

In December 1918 the State Optics Institute had been organized in Petrograd. It was one of the first scientific-research institutes in the country. Its founder and the first scientific adviser was Dmitri Sergeevich Rozhdestvensky, a professor of Petrograd University and eminent specialist in the field of optical physics. The Institute became quite a new type of scientific centre. It was Rozhdestvensky's idea that the underlying principle of its activity should be based on the closest possible interaction between science and technology and industry. Rozhdestvensky was indefatigable in reiterating that a physicist should be concerned not only with new discoveries, but should also be made fully responsible for their inculcation in industry. The Institute grew rapidly. By 1932 it had actually become a prominent scientific-research centre in the country; it focused on both the theoretical research in the field of optics and on problems of application. The Institute played an exceptionally important role in the creation of the Soviet optics and mechanics industry.

In 1932 Rozhdestvensky decided to resign from his busy scientific-and-managerial activities and concentrate his attention entirely on scientific research. The question that had immediately cropped up concerned who his successor in the capacity of the one in charge of the scientific research at the State Optics Institute would be (this post was that of assistant director). Rozhdestvensky could recommend no one else but the young Academician Sergei Vavilov. His candidacy was fully supported by A. Terenin and T. Kravets.

Academician A. Lebedev recalled that Rozhdestvensky had persuaded Vavilov to take on the scientific direction of the Institute, whose scope of activity was wide and diverse, and multilateral as far as the subjects it dealt with were concerned. The researchers were glad that their Institute could be privileged to have as its leader

a physicist of such renown as Vavilov. And Rozhdestvensky was more happy than anyone else.

In Leningrad Vavilov moved into a place on Birzhevaya Liniya (Line) on Vasilyevski Island. His work at the Institute became his principal concern, though he did not lose his contacts with Moscow University. Each time he came to the capital, he would ask about the work of his former colleagues.

At the State Optics Institute Vavilov found what was then considered to be a fairly large number of staff members (one hundred and sixty). The Institute was carrying out a vast programme of optical studies, which, as was mentioned, not only had theoretical significance, but was also directed at achieving practical goals. Those who worked at the Institute, in addition to Rozhdestvensky, were the future Academicians Aleksandr Lebedev, Vladimir Linnik, Aleksandr Terenin, Vladimir Fok; the future Corresponding Members of the USSR Academy of Sciences Yevgeni Gross, Torichan Kravets, Dmitri Maksutov, Sergei Frish; Professor Vladimir Prokofyev, Vladimir Chulanovski, A. Filippov; and other prominent men of science. One can readily imagine how difficult it was to not merely head this kind of collective formally, but to actually direct and guide it. However, Vavilov's versatility and his gift for speedily finding the right solution and getting down to the bottom of things enabled him to cope with the task that was set before him. He managed not only to coordinate various scientific trends at his Institute, but also to exert a marked impact on their development.

In determining the basic tasks that the Institute was to tackle Rozhdestvensky wrote, 'We should organize the work at the Institute in such a way that it would cover the whole range of both technology and science, or optical studies in all their integrity... It has to play the leading role in every branch of optics, optotechnology, photography, scientific optics, photochemistry and physicochemical processes connected with optical glass, and the problems of polish as well as optical pyrometry. The State Optics Institute is divided precisely into these sections and subsections, and for some years now it has been expanding on this wide scale and increasing the range of its departments. All the researchers of the Institute are fully aware of how propitious it is to cover the

entire field of optics in all its minutest details. This is exactly what makes us realize our advantage over the institutes in other countries.'

When Vavilov became head of the State Optics Institute and acquainted himself with its orientation, he fully approved of its activity as well as the programme for the Institute's further development that had been outlined by Rozhdestvensky. Under Vavilov's guidance the Institute not only continued to be the main research centre of the country in the field of optical studies, but also functioned as a branch institute of the optics and mechanics industry.

Vavilov wrote, 'The Institute has understood its function in the broadest sense of the word. Any scientific or technological problem in the field of optics that is worth being investigated can and even should be studied at the Institute. Optics should be covered practically in its entirety. This was precisely the trend that was gradually and persistently followed to result in the fairly complex structure of the Institute today with its numerous sections and laboratories. In each of these absolutely independent scientific units a relatively narrow range of optical problems is systematically studied. But overall, practically all of them are covered... Thus we come to the conclusion that the integrative character of our Institute is inevitable and serves much to its advantage at least until new and adequately efficient centres of optical studies appear in this country. Any kind of arbitrary division of such a large optical institute into specialized ones would, in our opinion, have a detrimental effect. The Institute is not an arithmetic sum of individual laboratories but an organic whole, whose significance is far greater than that of its sum.'

When Vavilov took the floor at the meeting of the scientific and technical council of the State Optics Institute on December 22, 1938 in connection with the twentieth anniversary of the Institute, he said, 'The task that unites the Optics Institute and the optics and mechanics industry in their joint efforts is in the long run reduced to providing the Soviet Union with optical instruments designed for the most diverse purposes. However, what is required of the Institute, it being a scientific organization, consists not so much in instrument-making as in determining the purposefulness of optical instruments and

the means by which their range of application could be widened. The significance of the latter can hardly be underestimated, and were it to be ignored, the assessment of the Institute's activity would be lopsided and erroneous.'

In 1932, at Dmitri Rozhdestvensky's suggestion, laboratory for luminescence analysis was organized at the Institute. Its name does not satisfactorily reflect its purpose, since the laboratory was mainly concerned with studying the fundamental processes of luminescence that reveal the nature of this phenomenon rather than conducting research directed along more practical lines. Vavilov was put in charge of the laboratory. Evgeny Brumberg, Boris Sveshnikov, and Aleksandr Shishlovsky, who were all from Moscow State University, began working with Vavilov. Later they were joined by Ivan Khvostikov, a young physicist from Leningrad, and Anton Sevchenko, a postgraduate from Byelorussia. Still later Viktor Zelinsky, Tatyana Timofeeva, Zinovi Sverdlov, Pyotr Feofilov and other specialists in luminescence came to work with them.

Professor Vladimir Prokofyev, one of Rozhdestvensky's pupils, told the author of this book that after Vavilov came to work at the State Optics Institute the situation there became somewhat peculiar. On the one hand, having become scientific director of the Institute, Vavilov was Rozhdestvensky's superior, but on the other hand, the laboratory for luminescence analysis was part of the science section of which Rozhdestvensky was the head. However, this did not in any way complicate the relationship between the two scientists whose trust and respect for each other remained intact. Moreover, they made every effort lest the other man's autonomy should be violated.

As head of the State Optics Institute Vavilov managed to unite into a single scientific body the scientific and production laboratories that focused on various optical problems. What helped him in this respect was his vast erudition and a talent for correctly evaluating the perspectives in the development of science as a whole and along its individual trends.

B. Neporent recalled that in 1937 the director's post at the Institute went to Dmitri Chekhmotaev. He was a man of no small will-power, full of zest and devotion to

business. However, he had come to the Institute from an industrial enterprise and did not have even the remotest idea of what scientific research was. At first he tried to make the Institute focus only on applied research and thus came into conflict with a number of scientists at the Institute. Vavilov did all he could to appease the arguing parties and retain the most optimal relationship between the fundamental and applied forms of research.

Academician A. Lebedev wrote that it was by no means easy for Vavilov to stand up for research focus of the Institute. In those days it was very often demanded of him to immediately assist in solving purely industrial problems, and thus he was obliged to explain the importance of scientific research for the further development of science itself as well as for industrial purposes. He did this with great tact and determination, always having a clear-cut idea of what the Institute's future should be.

A characteristic example of how persistently and painstakingly Vavilov tried to inculcate in the State Optics Institute the research that he considered to be promising can be illustrated by his attitude to the development of electronic microscopes. He succeeded in giving due credit to the new trend in microscopy at a time when the results that were obtained with the help of the new and imperfect instruments were considerably inferior to those obtained by means of the optical microscopes then in use. He also managed to successfully support the idea that it was necessary to continue the research, which as many considered had nothing much to yield in the future.

At the State Optics Institute Vavilov not only developed the studies on the quantum fluctuations of light, but also fully encouraged progress in any other kind of research that may have seemed to have nothing in common with the investigations in question. Thus, on his initiative, research was begun that resulted in the development of a new type of polarizing filter. E. Brumberg, who worked under Vavilov, suggested an original method of colour transformation. Research on the decamouflaging of various objects in the snow were carried out at the Institute. Studies of the stratosphere as well as comprehensive investigations in the field of illuminating engineering, photometry, physiological optics, etc. were also initiated.

Vavilov took a lively interest in everything that was being done. He gave his undivided attention, sponsorship,

and encouragement, and those involved in the research always had ample opportunity to get his advice. All this served to markedly promote his scientific authority and evoked the kindest feelings for him on the part of quite different people.

One of Vavilov's characteristic features was his constant concern not only for the whole Institute, but also for each one of its members, irrespective of his or her rank or merits. He always responded actively to anything that took place at the Institute, and willingly and not infrequently spoke before its members. What he said was invariably so profound and informative that there hardly remained anything to be added to what had already been explicitly rendered.

Vavilov was not a member of the Party, but in everything he did he always inflexibly and consistently adhered to the Party policy. B. Neporent stated that whatever Vavilov said or did served as an example to be emulated by every communist. Vavilov's authority was so great that his word was regarded as law. The members of the Institute never failed to do anything that he assigned, and he would make such requests in a most polite and personal way. He virtually became the heart and soul of his Institute.

In summer 1932 an expeditionary session of the USSR Academy of Sciences was scheduled to be held outside Leningrad. Its members were to acquaint themselves with the situation and demands of industry in Siberia and outline the measures that the Academy of Sciences could take in helping this very important region of the country. The academicians formed several groups and went to different cities of Siberia. Vavilov went with a group of people to Tomsk. During that trip Vladimir Komarov, the then Vice President of the USSR Academy of Sciences, on behalf of Aleksandr Karpinsky, the Academy's President, offered Vavilov the post of head of the Physics Department of the Physics and Mathematics Institute of the USSR Academy of Sciences.

At that time the Institute was a very small institution. Its staff consisted of a director, two heads of the departments, and four researchers. Over the period of fifteen years of Soviet government, the members of the Physics Department managed to accomplish only fifteen studies. Later Vavilov wrote: 'At one time (1931-1932) there

even existed a tendency to transform the Physics Department into a purely theoretical centre, connected mainly with the Mathematics Department of that Institute.'

Reminiscing about the Institute in those years, Ilya Frank said that anyone entering the building was met not by a doorkeeper but by a pleasantly ringing little bell that was attached to the door. Its sound, however, was not often heard. The basic scientific potential was concentrated at the State Optics Institute, the Leningrad Physico-Technical Institute and the Radium Institute, all of which did not belong to the Academy of Sciences. Regarding this state of things to be wholly unacceptable, V. Komarov set before Vavilov the task of transforming the small Physics Department into a multilaterally developed Physical Institute of the USSR Academy of Sciences.

Vavilov accepted the proposal and lost no time in reorganizing the Physics Department of the Physics and Mathematics Institute. In those days the Institute was situated in the right wing of the main building of the Academy of Sciences in Leningrad on Universitetskaya embankment. Recalling those years, Vavilov wrote: 'As a matter of fact, ever since 1933, under the common heading of the Physics and Mathematics Institute, there had actually functioned two separate institutes—one of physics, and the other, of mathematics. We, i.e. Academician I. Vinogradov and I, were virtually the duumvirate sharing nothing but a very good library.'

The main difficulty consisted in that there were not enough people. B. Vul recalled that A. Ioffe and D. Rozhdestvensky did not at that time support the idea of establishing the Physical Institute within the framework of the Academy of Sciences. Some time later, members of the Lebedev Physical Institute of the USSR Academy of Sciences even produced and hung on the wall a funny picture representing A. Ioffe and D. Rozhdestvensky as two sphinxes on the rocks amidst a stormy sea with a frail little boat bearing the sign 'The Physical Institute' between them.

Owing to Vavilov's efforts, the Physics Department rapidly developed and became consolidated. In the middle of 1938 Vavilov wrote, 'At present the Physics Department of the Physics and Mathematics Institute has twenty-six staff members and seven postgraduates. The number

of researchers is seventeen. The laboratory equipment is far from what is required; in particular, the mechanical workshop and the section where the glassblowers work need more space.'

Vavilov was most emphatically against the suggestion put forward by some members of the Presidium of the Academy to turn the Physics Department into a purely theoretical centre or to concentrate within it the studies on luminescence. He revealed no minor perspicacity in considering it absolutely essential for the Department to represent all the most promising trends in contemporary physics. In his opinion, the new Institute was eventually bound to become the centre of physical studies in the country.

A laboratory of the atomic nucleus and cosmic rays was one of the first to be organized. Since specialists were not available, Vavilov had to take the responsibility for its functioning upon himself at the very outset. This was not in any way a mere formality. Vavilov chose the subjects that were to be treated, and actively discussed how the research would be conducted with his colleagues. After Dmitri Skobeltsin moved from Leningrad to Moscow, he succeeded Vavilov as head of the laboratory.

Some time later Vavilov wrote, 'In 1933 the main researches of the newly reorganized Physics Institute were clearly defined. They were the following: (1) research into the properties of neutrons (that had recently been discovered), (2) the glow of liquids under the activity of radioactive radiation, (3) investigations on dyed crystals, (4) a series of analyses of the microstructure of liquids by employing the method of Brownian movement, Kerr effects, polarization of fluorescence, and dispersion of ultrasound, (5) investigation of electrical break-down in gases, and (6) electron diffraction and X-ray analysis of catalysts.'

Vavilov paid special attention to the studies of the structure of matter and, primarily, to nuclear physics, considering it to be a current trend of particular importance. This was where his foresight and the gift of opportunely assessing the significance of a new scientific trend were clearly manifested. It is particularly surprising because Vavilov had never worked in nuclear physics himself and did not associate his fate with the future research in this field. In those years, in spite of the fact

that the positron, and later, the neutron had already been discovered, nobody regarded nuclear physics as presenting any topical interest, and as far as its practical application was concerned, it was considered totally lacking in any prospects. One had to possess great courage and most resolute conviction to decide to make this branch of science one of the principal trends at the newly organized Institute.

To implement the research in nuclear physics Vavilov asked several young specialists to come and work with him. They included Leonid Groshev, Nikolai Dobrotin and Pavel Cherenkov. On Vavilov's advice his pupil I. Frank, whose educational background and aptitude were entirely within the province of optical studies, also undertook studies in nuclear physics. Vavilov had to exercise considerable effort to persuade Frank to agree to the change which he later did not regret. For the good of the cause Vavilov had not hesitated to deprive himself of one of his most gifted pupils and had directed his student to work in a branch of science that he himself did not think of making his own.

It was on Vavilov's own initiative that several investigations in nuclear physics were initiated at the Physics Department. L. Groshev and I. Frank studied the mechanism governing the creation of a pair of gamma-rays in a Wilson cloud chamber containing heavy gases. By employing the Wilson cloud chamber, N. Dobrotin studied the angular distribution of protons under the bombardment of a paraffin plate by a stream of neutron flux, and P. Cherenkov began investigating the glow of uranyl salt solutions under the effect of gamma-rays.

Recalling those years, I. Frank wrote, 'It was most fortunate to meet on one's road in life a man, who instead of saying "Nothing will come of it", was able to give his advice, which helped the work to be directed along such lines that something was bound to come of it. Vavilov was always ready to give this kind of advice, and it was much more valuable than a mere word of encouragement.'

The development of the young Institute was frequently hampered for no reason at all, and unexpected impediments constantly cropped up on its way to progress. I. Frank recalled the following, 'The first steps in nuclear physics at the Institute were not devoid of difficulties. The Institute was often subjected to inspection and criticism.

If an official commission was reviewing the Institute it would note that since nuclear physics was a useless science, there was no basis whatsoever for its development. When the discussions were held at the Academy of Sciences the criticism was based on quite different grounds. It was asseverated that none of the acknowledged scientists there had anything to do with nuclear physics, and that the younger researchers would hardly be able to succeed in the field... Vavilov himself was subjected to criticism for the work that was carried out by Cherenkov. However, Vavilov remained adamant, and research in the field of nuclear physics at the Lebedev Physical Institute of the USSR Academy of Sciences was continuously expanding. The absence of recognized authorities did not discourage Vavilov. He invariably relied on the younger generation. Once having been convinced that the young researcher was really talented, he insistently encouraged his preferment and actively promoted the research to a successful outcome. It is not surprising, therefore, that many leading scientists are known to have received Vavilov's scientific guidance.'

Sergei Ivanovich liked to talk with Moisei Markov, the young theoretician and future Academician, with whom he would discuss the latest problems in nuclear physics for hours on end. Vavilov would often ask the same question, 'Well, and what is in the air?' By this he meant news about elementary particles. He used to light a cigarette and settle down in his armchair, thus making it clear that the time for a serious discussion had come. But when it did start, an unrestrained atmosphere of confidence enjoyed by the two speakers invariably made itself be felt.

When Vavilov heard of a newly discovered elementary particle he would joke, 'With every new day, we have something new to say.' Markov used to say that Vavilov had a remarkable gift for actually feeling what problems concerned his interlocutor. It was easy to talk with him about new ideas that one could not as yet formulate coherently. In cases like these Vavilov liked to quote from his favourite literary work *Faust*: 'Words are the weavers of what we discuss, they give us systems, working thus.'

Vavilov's influence on the life of such an outstanding scientist as Igor Kurchatov can hardly be overestimated. It was quite opportunely that he focused his attention on

this highly gifted physicist and helped him to attain his first success. In 1934 when the degrees of "Doctor" and "Candidate of Sciences" were introduced in the USSR, Vavilov together with Abram Ioffe applied to the higher commission that conferred scientific degrees with a request to have Kurchatov receive the degree of Doctor of Physics and Mathematics without having to defend a dissertation. Permission was granted, and Kurchatov was made Doctor of Sciences for the sum total of his research in the field of dielectrics, the discovery of ferroelectricity, and the study of gaseous discharge. This was exactly the same case with Pyotr Kapitsa, the prominent physicist, corresponding Member of the USSR Academy of Sciences who, on Vavilov's recommendation, was elected Full Member of the Academy in January 1939.

In September 1933 the First All-Union Conference devoted to studies on the atomic nucleus was organized at the Leningrad Physico-Technical Institute. It was arranged to coincide with the fifteenth anniversary of the Institute. In addition to the Soviet scientists there were many eminent participants from other countries. Vavilov, who was a member of its presidium, took a very active part in its activities. The problems that were discussed there convinced him even more that the general trend of research at the Physics Department was tenable in all respects.

The young researchers injected new life into the department. The laboratory facilities were renovated and increased in number. Some very important research was accomplished between 1933 and 1934. Vavilov's postgraduate P. Cherenkov discovered a new type of glow, which was later called Vavilov-Cherenkov radiation, N. Dobrotin clarified the law of collision of neutrons and protons, B. Vul established the dielectric strength of gases, S. Artsybashev worked out the method of dying crystals, etc.

In 1934 a decision was adopted to transfer the USSR Academy of Sciences from Leningrad to Moscow. By that time the Physics and Mathematics Institute had already been divided into the Steklov Institute of Mathematics and the Lebedev Physical Institute of the USSR Academy of Sciences. The name given to that Institute had been suggested by Vavilov, who explained that the name of Lebedev brought together old academic physics and its

present-day state of development. One of the first to move to the capital was the Physical Institute. It was housed in the building of the former Physics and Biophysics Institute of the RSFSR People's Commissariat of Health on 3rd Miusskaya Street.

The transfer of the Lebedev Physical Institute of the USSR Academy of Sciences to Moscow created quite a few problems for Vavilov, since it was decided that he should remain scientific director of the State Optics Institute. Vavilov continued to live in Leningrad, but for almost eight years he used to come to Moscow two or three times a month to supervise the work of the Physical Institute. Vavilov never complained of his dual responsibility. Professor Maria Konstantinova-Shlezinger said that Vavilov never tired of the train trips he had to take so often. He told her that he got used to enjoying his rest while travelling. From the railway station he would immediately rush to various places that he had to visit on business, so that half an hour after 'The Red Arrow' came to its terminus from Leningrad, one could often hear his low soft voice in either of the laboratories at the Lebedev Physical Institute or the Academy of Sciences or at the Publishing house of the USSR Academy of Sciences.

The Lebedev Physical Institute was allotted what was then considered to be a large building. New possibilities of conducting scientific research on a wide scale had thus emerged. However, again there was a shortage of highly qualified specialists, since only thirty people agreed to leave Leningrad for Moscow.

At that time the only really large physics institution in Moscow was the Physics Institute of Moscow University. Vavilov asked many of its scientists to join the Lebedev Physical Institute of the USSR Academy of Sciences. Those who agreed to work there included Dmitri Blokhintsev, Vladimir Veksler, Grigori Landsberg, Vadim Levshin, Mikhail Leontovich, Leonid Mandelshtam, Pyotr Rebinder, Sergei Rzhevkin, Igor Tamm and other well-known physicists.

Yevgeniy Feinberg, a corresponding Member of the USSR Academy of Sciences, recalled that someone had once said, 'What a remarkable person Sergei Ivanovich is! He was not afraid to give jobs to those who were in no way inferior to himself.' As time had shown, the atmo-

sphere of mutual confidence and respect created by Vavilov at the Lebedev Physical Institute of the USSR Academy of Sciences excluded any possibility of envy, quarrels, and conflicts.

The research work at the Institute rapidly gained momentum. Nine laboratories were organized. They were: the laboratory of the atomic nucleus (D. Skobeltsin), the laboratory of the physics of oscillations (L. Mandelshtam), the laboratory of physical optics (G. Landsberg), the laboratory of spectral analysis (S. Mandelshtam), the laboratory of the physics of dielectrics (B. Vul), the laboratory of theoretical physics (I. Tamm), the laboratory of acoustics (S. Rzhevkin, to be succeeded by N. Andreev in 1940), and the laboratory of surface phenomena (P. Rebinder). Vavilov himself was in charge of the luminescence laboratory.

In May 1935 Vavilov was sent abroad to acquaint himself with how research in the field of optical studies and the optics industry were organized. The trip lasted for two and a half months. Vavilov visited optical laboratories and plants in Paris, Berlin, Warsaw, Vienna, Florence, Rome, Milan, Genoa, and Brussels.

In Europe he gave several scientific reports. A particularly important one was given at a joint session of the National Optics Institute and the Italian Association of Electrical Engineering in Florence, where he spoke of his research on quantum fluctuations of light and acquainted those present with the research in optics that was carried out in the Soviet Union. Some time later, when recalling the speech Vavilov made, V. Roncci, the Director of the National Optics Institute, wrote, 'In many respects we found that Vavilov knew much more than we did. He was aware of things that we had never heard of before. In addition, he had a perfect command of the language, and was, in general, a highly cultured person.' Vavilov took part in a congress on scientific photography and in the Astronomical Congress in Paris.

Vavilov spent much time working in Italian and French libraries since he was to edit the Russian edition of Newton's works. Meanwhile, he became thoroughly acquainted with the history of the photometric method of light quenching, in which he was particularly interested because of his research on the quantum fluctuations of light.

The trip to Europe proved to be very auspicious. Later Vavilov wrote that what he had seen in the institutions abroad was highly instructive for him ('a living scale for the assessment of the Optics Institute'). After learning about the optics institutes in Paris and Florence the State Optics Institute proved to be in no way inferior and actually surpassed them as far as several scientific trends were concerned. Vavilov said that in Paris he happened to see research on interferometry and optical glass that was based on the publications of the State Optics Institute. At the same time he became convinced that the Soviet specialists in optics had to learn something from their colleagues in the West.

He pointed out that the small institutes in Paris and Florence had one very important advantage over the State Optics Institute: their influence on industry was undeniably greater. These institutes also had no minor experience in training engineers and technical specialists for the optical industry. It was this experience that Vavilov successfully implemented at the State Optics Institute some time later.

A letter that was sent to V. Levshin by Vavilov from Paris was preserved in Levshin's home archives. Its unabridged text is as follows:

30 June 1935 *Paris*

Dear Vadim Leonidovich,

Yesterday the Italian, and most interesting part of my travels came to an end. I became very well acquainted with the state of Italian optics, visited all the main plants, and became fully aware of what the Optics Institute in Florence is, as well as of the state of physics in Italy. The state of physics is, on the whole, deplorable. It is conditioned by the fact that nobody wants to pay for 'pure' physics. In most favourable circumstances money can be obtained only for the purchase of equipment, while the sums allotted to salaries are too meagre for anyone to subsist on, and no new jobs are made available. There are hardly a sufficient number of people who want to take up physics as their profession, and those who have already become specialists in this branch of science (as, for instance, in Fermi's laboratory) think of

leaving their country for the USA. In the whole of Italy there are not more than twenty professors of physics, fifty per cent of whom are either past the threshold of senility or are cerebrally inadequate. One can find real physics only with Fermi in Rome (with only five people working in his laboratory). Optics here is treated only in technical terms, and can thus live and flourish. The Optics Institute is a very small establishment, though strong and viable. Up till now its task consisted in working out calculations, conducting experiments, and doing design work for plants. Now the Institute is growing, and there will be illumination engineering and photographic sections in it, and I think that in the course of time it will become an institution very much the same as the one we have in Leningrad. It has achieved the status of the industry's technical commander, with the industry having attained a level within the past five or six years on which it can very well compete even with the Germans. I became acquainted with all the specialists in optics, made certain practical conclusions, and think that in this respect my trip to Italy was highly profitable. It was sad to leave that country: the people, nature, and everything about Italy being so good, in spite of all fraudulent machinations on the part of its fascist leader.

Yesterday I arrived in Paris. Today is Sunday, and I'm trying to see as much as possible of the French capital. Tomorrow I shall have a talk with Fabri and start doing something useful. Paris is indeed a city of high style, with no traces of ostentatious splendour and even a fair amount of mud in its streets. But the people here know exactly what they want and are completely aware of how to attain it.

It is most unfortunate that I get so few letters from the Institute, and for these one-and-a-half months I have been feeling as if I were separated from it completely. As far as fluorescence is concerned, I had quite a few talks on this subject in Warsaw, where I became acquainted with many people. The one who produces the most favourable impression of a highly gifted person is Jablonsky, who will undoubtedly make a prominent physicist.

What it all boils down to remains the same. You and I ought to chuck all other things and start writing our book in earnest. Otherwise the results (which, as you know, are numerous) will never see the light. I am planning to roll

up my sleeves first thing after I get back home. I shall shortly find out whether there is any chance for me to see Pringsheim. I'll do my best to contact Perrin, and start the negotiations about the possibility of your coming to Paris and Brussels (so begin learning French now).*

With kind regards to your wife, son, and all our Institute colleagues,

Yours, S. Vavilov.

During his travels in Europe Vavilov tried not to confine himself to optical problems alone. He was also interested in problems that concerned physical science as a whole. He was particularly keen to become acquainted with the results obtained at the laboratory of the Italian physicist Enrico Fermi in Rome. Of particular interest were the experiments on measuring the velocities of thermal neutrons.

Vavilov tried to introduce what he saw in Europe that was of practical significance to the research of the State Optics Institute, and later, of the Lebedev Physical Institute of the USSR Academy of Sciences. The knowledge of methods of organizing scientific research also proved to be useful for Vavilov when he became President of the USSR Academy of Sciences.

Speaking of those years when the Lebedev Physical Institute was in a state of organization, B. Vul said that Vavilov was mainly concerned with consolidation of the Institute as a whole rather than with his own research. I. Frank was quite explicit about the fact that during his travels in Europe Vavilov never stopped thinking of the Physical Institute—the product of his creative activity. Moreover, he showed exactly the same concern for his own laboratory as for all the others.

The particular aid Vavilov rendered to the laboratory of the atomic nucleus can be seen from his letter to I. Frank

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* In those years Vavilov's plans were not destined to be realized. It so happened that he and Levshin never managed to write the book together. In 1936 Levshin published his work *Luminous Compounds,* which was the first Soviet monograph on phosphor crystals (Vavilov did not work on these problems). In 1951 Levshin published the monograph *The Photoluminescence of Liquids and Solids,* where the results of his work with Vavilov on luminescence were presented in a generalized form. Vavilov had the chance to bring together his research in the field of optical studies only a short time before he died: in 1950 he wrote his monograph *The Microstructure of Light.*

in which he wrote: 'There is some good news about the equipment; I have brought a litre of xenon from Paris; heavy water will probably be available too; polonium has been ordered, and there is some hope that we shall get radiothorium too.'

Further Vavilov gives an outline on what is to be done in nuclear physics research in 1936: 'Dobrotin is planning to think over Fiso's experiment with slow neutrons; Vernov will be doing cosmic rays; Cherenkov will continue his work with the glow under the activity of γ-rays; and the contract with Skobeltsin is in preparation.'

The letter ends with the words: 'On the whole I think that the laboratory is moving in a direction that in a year or two will bring the desired results.' The director of the Lebedev Physical Institute was as considerate of all the other scientific trends.

Shortly after his return from abroad Vavilov visited the Leningrad Physico-Technical Institute, which was headed by A. Ioffe. What interested him most of all was the research that was carried out in nuclear physics. After Vavilov acquainted himself with the research conducted in the laboratories, he had a talk with Abram Ioffe. Vavilov spoke of the impression that the Institute produced upon him, and laid particular stress on the fact that the centre of research in physics was now being directed towards the atomic nucleus. What troubled Vavilov was the fact that in this country investigations of this kind were so far disconnected and not appropriately coordinated. He believed that research in nuclear physics should be concentrated in one of the academic institutes.

In March 1936 a special session of the USSR Academy of Sciences was convened, whose task was, as was stated by Vladimir Komarov, the then President of the Academy, to bring to light the achievements of Soviet physics against the general background of what had been attained in physical studies on a worldwide scale. The agenda included summary reports by Academician A. Ioffe, the Director of the Leningrad Physico-Technical Institute, and Academician S. Vavilov, the scientific adviser of the State Optics Institute. The latter institute was also represented by Academician D. Rozhdestvensky, who gave a report on spectral analysis.

At the session there was much debate about the problems of physics in the USSR and its perspectives. The attitude

to the reports submitted by the two most prominent physical institutes was different. Ioffe's report had evoked serious criticism. Nobody failed to mention the outstanding role that Academician Ioffe played in the foundation of physics in the USSR and the organization of the Leningrad Physico-Technical Institute. However, there wasn't a single person who would share the speaker's optimistic assessment of the state of Soviet applied physics. Most of those present did not support Ioffe's statement that physics should take on the functions of an adviser of technology rather than its guide and that the practical applications of physical discoveries should be the concern of industrial laboratories and specialized institutions and not physical institutes. Rozhdestvensky and Vavilov most emphatically rejected this proposition.

In its resolution the session made a special mention of the fact that, in a number of cases, the Leningrad Physico-Technical Institute had confined its research only to an initial stage, as a result of which the West European physicists took the lead. The connection between theory and experimentation was found to be inadequate. It was pointed out that a proper relationship between physical studies as such and their practical application in the national economy had not been established, which hampered the rational use of scientific research by the industry.

In his report at the session Vavilov spoke of how the central optics institution in the country came into being. He disclosed the daily contact that existed between his Institute and the optics and mechanics industry and dwelt at some length on the fundamental optical studies that were conducted at the Institute, laying particular stress on their vital importance not only for optics, but also for physics in general. The report produced an enormous impression. Everybody said that the speaker had raised a number of highly significant problems, and the report as a whole was perspicacious and presented in the most brilliant manner.

Concluding his report, Vavilov said: 'The research we are conducting as well as the achievements of Soviet science are being confronted with the same cautious attitude that was directed at the Soviet state and its possibilities in their time. But I am positive that in the course of time and as we accumulate more and

more remarkable and first-rate research produced in the years following the Revolution, this particular lack of confidence in what is being done by us shall be completely dissipated. Moreover, can this mistrust be regarded as something essential? What we ought to teach ourselves is to be our own judges in the strictest sense of this word.'

The meeting of the Academy made an entry in its resolution, which said that the State Optics Institute was one of the few physical institutes in the country that from its very outset had established firm ties with the industry.

This session of the USSR Academy of Sciences was of great significance. It provided the institutes of the natural sciences with an orientation that directed their development along the lines presupposing a close link between the solution of fundamental problems and the research essential to the rational implementation of what was of current importance. Vavilov always thought about this himself. He used to point out that scientific institutions had no right to disregard the vital tasks of industry nor, at the same time, to confine their activities to a narrow field of practicality. Vavilov considered both these tendencies to be in no way favourable for the development of science.

In the following years Vavilov made every possible effort to promote the further strengthening of the ties between the State Optics Institute and the optics and mechanics industry of the country. He devoted much time and work to make the latest scientific achievements in optical studies accessible to industry within the shortest time possible. His service in the development of the optics and mechanics industry of the USSR received a high token of appreciation as far back as the thirties. In 1939 he was awarded the Order of the Red Banner of Labour.

Time was on its march and nuclear physics was rapidly progressing. It had become evident that research in this field was promising not only for science, but also for purely practical purposes. At the end of 1938 the Presidium of the USSR Academy of Sciences heard Vavilov's report on the organization of atomic nucleus research. It was decided that research on the atomic nucleus and cosmic rays should be concentrated entirely at the USSR Academy of Sciences, as well as in the Academies of the Ukraine

Representative of the State Committee for Defence, 1943.
(The photograph is published for the first time.)

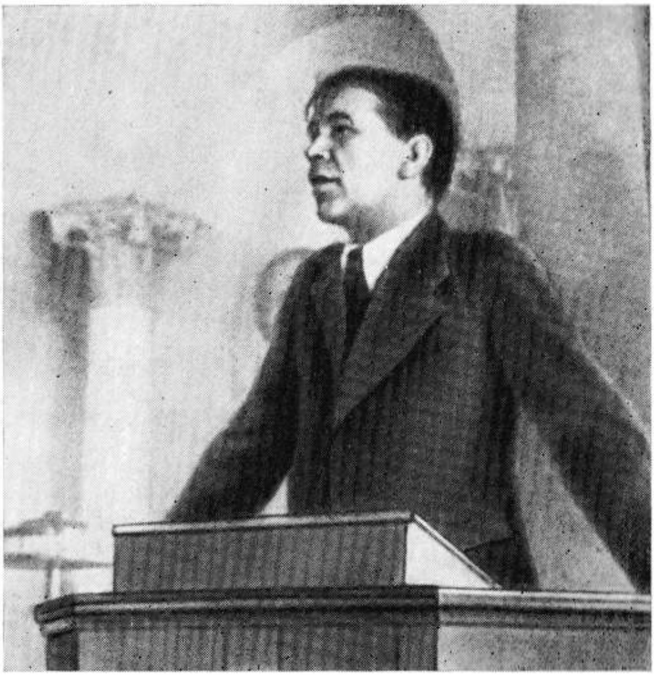
S. Vavilov with members of the State Optics Institute. In the bottom row: B. Sveshnikov, E. Brumberg, S. Vavilov, and A. Sevchenko. In the top row: V. Zelinsky, T. Timofeeva, P. Feofilov, V. Molchanov, Z. Sverdlov, and M. Grushvitskaya. Ioshkar-Ola, 1944.

S. Vavilov, 1945.

In the bottom row: Academicians S. Nametkin and V. Komarov. In the top row: Academicians S. Vavilov and A. Ioffe, 1945.

Reception of foreign guests at the Lebedev Physical Institute of the USSR Academy of Sciences at the commemoration of 220 years of the Academy. S. Vavilov, S. Penkovsky, G. Landsberg, and Max Born, June 19, 1945.

S. Vavilov in his study at the Presidium of the USSR Academy of Sciences, 1947.

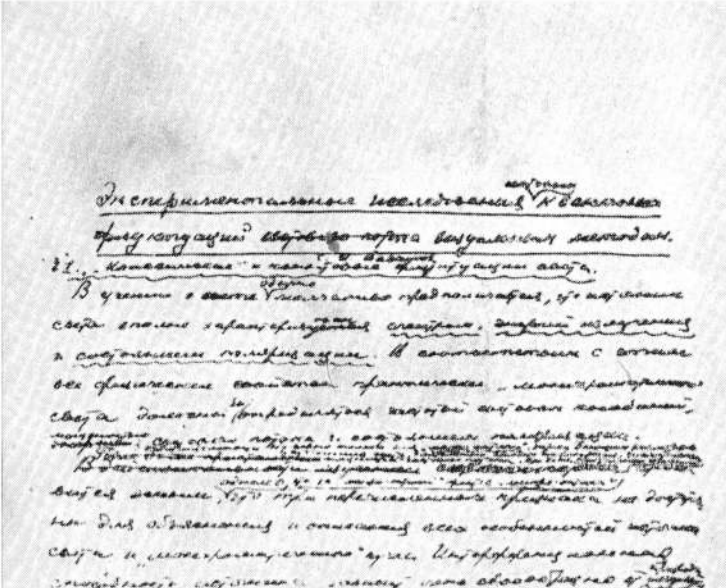


S. Vavilov taking the floor on the day he was elected President of the USSR Academy of Sciences, July 17, 1945.

S. Vavilov in his study at the Lebedev Physical Institute of the USSR Academy of Sciences holding instruments designed by P. Lebedev, 1947.

A. Terenin, V. Levshin and S. Vavilov in the Presidium of the second All-Union Conference on luminescence studies, 1948.

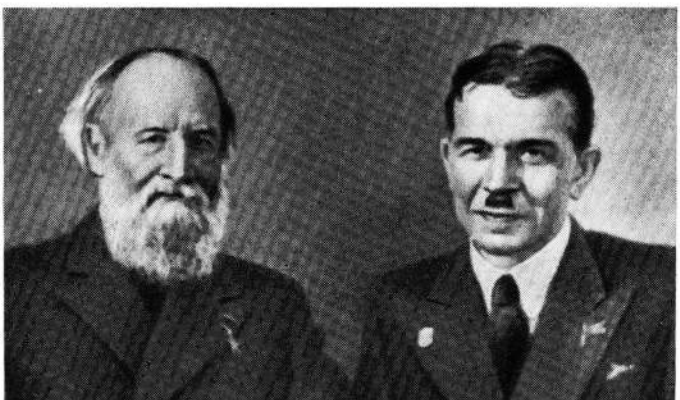
A report on the migration of excitation energy at the second All-Union Conference on luminescence studies, 1948.



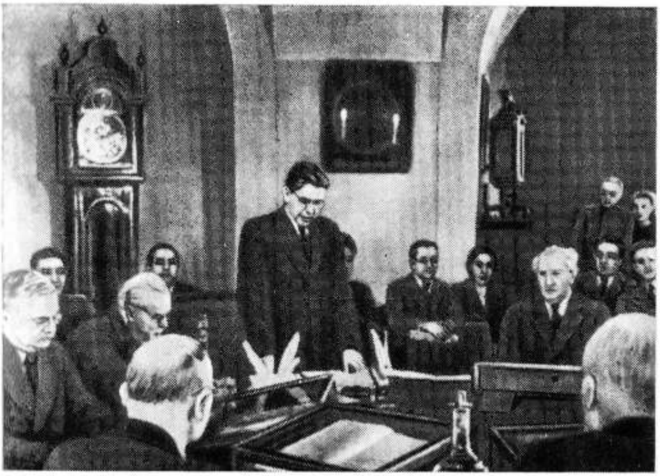
A page from the first draft of S. Vavilov's handwritten monograph *The Microstructure of Light*.

S. Vavilov next to the first high-pressure luminescent lamp in the laboratory of the Lebedev Physical Institute of the USSR Academy of Sciences, 1941.

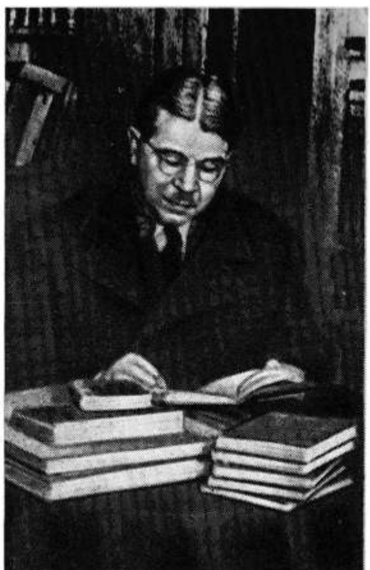
A badge of the Publishing House of the USSR Academy of Sciences as designed by S. Vavilov.



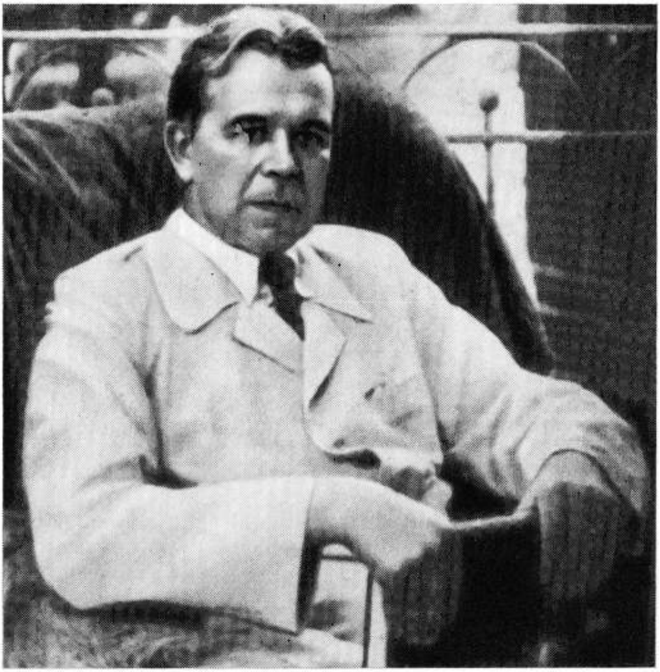
Academicians A. Krylov and S. Vavilov during the Jubilee Session of the USSR Academy of Sciences, 1945.



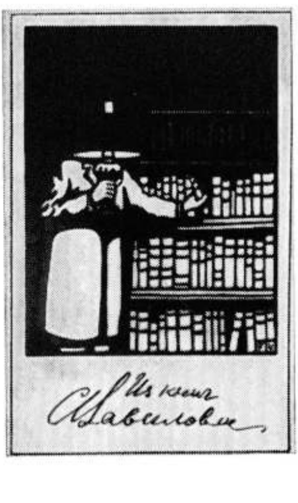
Vavilov giving the introductory speech in the circular hall of the Chamber of Curiosities at the opening of M. V. Lomonosov Museum, January 5, 1949.



Vavilov looking through books, 1949.



In the Moscow suburban sanatorium 'Uzkoye', 1949.



S. Vavilov's 'Ex-libris'.

S. Vavilov with his grandson Sergei, 1950. (The photograph is published for the first time.)

S. Vavilov gold Medal in Physics.

S. Vavilov's portrait painted for the Physics Faculty of Moscow State University by I. Kosmin, 1952. (The photograph is published for the first time.)

A postage stamp with a portrait of S. Vavilov issued to mark his seventieth birthday, 1961.

A drawing from the postal envelope with the image of S. Vavilov Medal, issued on the twenty-fifth anniversary of the All-Union Society 'Znanie'. 1972.

A sculpture of S. Vavilov in the vestibule of the Physics Faculty of Moscow University. (The photograph is published for the first time.)

and Byelorussia. The Presidium had decreed that the Radium Institute in Leningrad be reorganized and a new building for the Lebedev Physical Institute of the USSR Academy of Sciences be built so that basic research in nuclear physics could be concentrated in Moscow.

The Presidium organized a commission on atomic nuclear studies at the Physics and Mathematics department of the USSR Academy of Sciences. Vavilov was appointed its chairman. This measure was taken to help in the planning and management of research on the atomic nucleus, in avoiding duplication of research at individual institutes, and the convocation of conferences on the atomic nucleus. Thus, Vavilov's outstanding role in the establishment and organization of nuclear physics in this country had received its acknowledgement.

In Leningrad, the research in nuclear physics was directed by L. Mysovsky. However, since he did not want to move to Moscow, D. V. Skobeltsin was made responsible for the laboratory of atomic nucleus studies. His research on the interaction of γ-rays with a substance, conducted with the help of a Wilson cloud chamber, had already been widely known. Even before he took up his duties as head of the laboratory he, also a Leningrader, now and then came to Moscow to offer his advice to the people at the Lebedev Physical Institute. It took him quite some time to make up his mind to leave his native city for good, because, in his opinion, the Lebedev Physical Institute already had a body of highly-qualified specialists and was thus in no urgent need of his help. However, Vavilov insistently tried to persuade him to change his mind.

Skobeltsin told the author of this book that once, in answer to his refusal to move to Moscow, Vavilov had jokingly said, 'The Lebedev Physical Institute needs you badly. In every stable there should be a goat to scare off the goblin.' In 1939 Skobeltsin did come to Moscow to remain with the Lebedev Physical Institute for the rest of his life.

In the beginning of 1940 the Lebedev Physical Institute of the USSR Academy of Sciences was under inspection by a commission representing the Presidium of the Academy. Those who were supposed to assess the work of the Physical Institute did not have even the remotest connection with physics. Thus, the commission doubted

whether the further development of research along the lines that had been elaborated was of any use at all. Skobeltsin recalled that the discussion of the results of the work of the commission was held in the conference hall of the Academy's Presidium. The biased criticism had evoked Vavilov's vehement reaction. This man, who had always been perfectly poised, became furious, and banging his fist on the rostrum, demanded that the Institute should be left in peace. He unambiguously said that it was impossible that its members should be compelled to do nothing for such a long period of time. And thus the Institute managed to defend and uphold its research.

Vavilov saw only too clearly that no tangible success in nuclear physics could be attained without a large charged-particle accelerator. At his own initiative, a cyclotron team was formed at the Lebedev Physical Institute in 1940 to elaborate the accelerator project. The team included the young physicists V. Veksler, S. Vernov, L. Groshev, P. Cherenkov, and E. Feinberg. Their work was interrupted by the outbreak of the war. In the postwar period, the Lebedev Physical Institute of the USSR Academy of Sciences saw the construction of an electron accelerator rated at 250 MeV.

In spite of the difficulties, the Lebedev Physical Institute was most definitely expanding. It had become clear that the cosy little building in Miusskaya Street could no longer meet the Institute's demands. The design for a new building was worked out under Vavilov. The Institute was to be located beyond the part of Moscow that was called Kaluzhskaya Zastava (not far from what is now known as Gagarin Square). In this case too the work was impeded by the war. Only several years after it ended, and already after the death of Sergei Vavilov, the new Institute was built. E. Feinberg estimated that over the period of seventeen years during which Vavilov was the Director of the Lebedev Physical Institute, its staff and the area it occupied increased by 100 times.

In the thirties research on the stratosphere was being intensively developed in the Soviet Union. In September 1933 the Soviet stratospheric balloon 'USSR-1' reached a record height of 19 thousand metres.

In December 1933 the organizing committee of the First All-Union Conference on studies of the stratosphere,

with Academician Vavilov as its chairman, started functioning. The conference was held in Leningrad between March and April of 1934, and, as Academician D. Skobeltsin said, 'covered an enormously wide range of problems.'

In his opening speech at the conference, Vavilov said, 'The conference has to adopt a resolution concerning the most rational designs of stratospheric balloons, their floating and rocket flights.' It was decided that a commission responsible for stratosphere studies be organized: it first functioned at the Lebedev Physical Institute and then came under the control of the Presidium of the USSR Academy of Sciences.

Vavilov was appointed chairman of this commission. He was one of those who enthusiastically encouraged the creation of a new branch of the physics of the atmosphere, the aerology, that deals with the phenomena of the free air. It was already after the war and at the time when he was President of the USSR Academy of Sciences that Vavilov rendered invaluable support to the organization of the Central Aerological Observatory in the Moscow regional town of Dolgoprudnoye. He had been in charge of the commission on stratosphere studies until 1938, the year its functions were taken over by the Institute of Theoretical Geophysics of the USSR Academy of Sciences. Vavilov was its dedicated proponent and did very much to encourage the study of the stratosphere at high altitudes.

In 1934, Vavilov supported the initiative of the future Academician Gleb Frank on the organization of the combined high-mountain Elbrus expedition of the USSR Academy of Sciences. In summer 1935 this expedition was sanctioned by the Presidium of the Academy. A. Ioffe was appointed its chairman, with Vavilov as his deputy, and I. Frank as scientific secretary. The expedition functioned until 1938, and a number of institutes took part in it. Members of this expedition managed to cover a wide range of research in the field of physics, radio engineering, and physiology. Everything that was done by the expedition entered into the research programme that was under the general guidance of the Commission on stratosphere studies. Those taking a very active part in it included groups of researchers from the State Optics Institute and the Lebedev Physical Institute of the Academy of Sci-

ences. They carried out investigations on atmospheric phenomena and cosmic rays. As was suggested by Vavilov, atmospheric sounding by means of the projecting ray was initiated.

I. Frank, one of the members of the expedition, wrote: 'At that time we conducted our first observations of cosmic rays at different heights ranging from 3000 m (Terskol) to 4300 m (Priyut odinnadtsati). A Wilson cloud chamber was used for these purposes. In addition, on Vavilov's advice, we, together with a group from the State Optics Institute consisting of Academician A. Lebedev and I. Khvostikov, did some research on the glow of the nightsky. The circumstances under which we worked, particularly those in which the cosmic rays were studied, were then still highly unfavourable. In order that the radioactive background be minimal, we were obliged to work on the glacier itself, and moreover without even a tent... This was the beginning of a series of investigations on cosmic rays, which were conducted in the Elbrus expedition in the following years mainly by V. Veksler and N. Dobrotin. In about the same period S. Vernov employed the method of cosmic-ray balloons that were invented by Molchanov for the observation of cosmic rays. Several years later he undertook a marine expedition to the equatorial latitudes, which resulted in the discovery of a marked latitude effect of cosmic rays in the stratosphere. I can still remember how during the discussion of this work at the Academy of Sciences Vavilov defended S. Vernov's results from the attacks of those who were making references to authorities who had not succeeded in receiving this kind of result.'

In 1940 S. Vavilov presided over the first conference on the visibility and transparency of the lower layers of the atmosphere at the State Optics Institute. Vavilov's authority in these problems was so great that one year before the Presidium of the Academy, when organizing the academic board of the Institute of Theoretical Geophysics, which was represented by such prominent geophysicists of the country as Academicians Otto Yulievich Shmidt, Pyotr Lazarev, Vassili Fesenkov and others, made him one of its members.

The interest in the stratosphere, which Vavilov had entertained for many years, brought him to the research connected with the extra-atmospheric medium. Already

between 1933 and 1935, together with Dmitri Rozhdestvensky, he organized a group of astrophysicists, which included Viktor Ambartsumyan, Nikolai Kozyrev, Grigori Shain and some of the other members at the State Optics Institute. This group carried out a fairly large number of investigations presenting no minor astrophysical interest.

Vavilov was one of the first Soviet scientists who supported the pioneer research of the engineer and inventor Pavel Oshchepkov and the proposals on the radio-detection (radiolocation) of planes put forward by Pavel Khoroshilov, the representative of the headquarters of the country's anti-aircraft defence. In 1933 they were directed to Vavilov by Aleksandr Karpinsky, the then President of the Academy.

Oshchepkov had this to say about their meeting: 'S. Vavilov is an exceptionally charming person, who did not start asking any details about our task. He immediately grasped the sum and substance of the problem and began discussing it. His unusually deep knowledge of the history of technology and his ability to appreciate the role and significance of the hypotheses that were advanced in the development of science and technology helped him to firmly and unambiguously get himself on the path substantiating the tenability in putting forward the task concerning the electromagnetic detection of an object.' At the end of our talk Vavilov said, 'I am a confirmed optimist as far as everything new is concerned, and I am not afraid of anyone disagreeing with me. However, we could get together and discuss it all over again. I am quite ready to help you with your initiatives.' Many years later, when he was President of the USSR Academy of Sciences, Vavilov helped Oshchepkov with his research in the field of introscopy (the science dealing with the production of real-time images of the internal structure of an object that is opaque to light).

Vavilov was greatly interested in the building of the House of Soviets in Moscow. The elaboration of the plans for this monumental building (which were not realized) presented a large number of diverse problems for its designers. The acoustics of the building were beset with difficulties: in particular, the planning of the Grand Hall of the House of Soviets, with a diameter of 160 metres and the height of the dome measuring 80 metres,

caused quite a problem. In 1937 a group of scientists working in acoustics was asked to help with the solution of these problems. Those in charge were Nikolai Andreev, a Corresponding Member of the USSR Academy of Sciences, and Professor Sergei Rzhevkin.

In May 1939 a session of the Physics and Mathematics Department of the Academy was convened. It was devoted to the acoustics problems in the House of Soviets. Vavilov was the chairman. The reports of those working on the project were discussed at the session, with Vavilov drawing special attention to the necessity of including the mathematicians in the work. He addressed them directly, and they responded immediately. Among them there were the future Academicians Lev Pontryagin and Vladimir Fok. The work they did was not in vain. Owing to their efforts it became possible to solve a number of highly important problems in architectural acoustics.

Vavilov had numerous assignments from the Presidium of the USSR Academy of Sciences, of which he was elected a member in 1935. The same could be said as regards the Physics and Mathematics Department of the Academy, where he had served in the capacity of Deputy Academician-Secretary since 1939. From 1936 Vavilov worked in the Departments of Technical Sciences, Applied Physics and Applied Chemistry. In 1938 he was confirmed as Member of the Commission on Conferring Scientific Degrees of the All-Union Higher School Committee.

In those years he headed the USSR Academy of Sciences commission responsible for the publication of popular science literature, and the USSR Academy of Sciences commission on history; he was also a member of the academic committee concerned with the training of specialists, the commission dealing with technical equipment and the administrative board responsible for propaganda on scientific achievements. Vavilov was a member of the USSR Academy of Sciences commission connected with studies on the propagation of radio waves, spectroscopy and others; he was on the editorial board of a dictionary of contemporary Russian, and was a member of the committee on meteorite studies, the scientific council of the Institute of Theoretical Geophysics, the Physico-Technical Institute, and others.

Vavilov was in charge of the physics and mathematics section of the Institute of the History of Science and

Technology of the USSR Academy of Sciences, a member of the editorial board of the Academy, as well as of the scientific periodical *Doklady Academii Nauk*, and managing editor of the *Zhurnal Eksperimentalnoy i Teoreticheskoy Fiziki*. In addition to all this Vavilov honourably carried his duties as Deputy of the Leningrad Soviet of Working People's Deputies and a Deputy of the USSR Supreme Soviet. Vavilov's enormous activities as a scientist, organizer, and social worker made him very popular and stand shoulder to shoulder with the leading scientists of his country.

In March 1941 Vavilov marked his fiftieth birthday. At that time he happened to be in Moscow and it was decided to celebrate his jubilee at Vadim Levshin's flat in Bolshaya Yakimanka (now Dimitrov Street). Among the guests were B. Vul, G. Landsberg, V. Antonov-Romanovsky, M. Konstantinova-Shlezinger, and other members of the Physical Institute. I was only thirteen then, but I can very well remember that we all had a wonderful time together.

THE VAVILOV-CHERENKOV EFFECT

In 1933, as was already mentioned, Vavilov suggested that P. Cherenkov, his postgraduate, begin studying the luminescence of solutions of Uranyl salts excited by the γ-rays of radium and compare it with the glow of the very same substances when they are excited by visible light and X-ray radiation.

The research topic did not receive the support of some of the influential people at the Academy. I. Frank and E. Feinberg wrote that they remembered very well the contemptuous remarks that claimed that the Lebedev Physical Institute was occupying itself with watching spectres and a fruitless quest of some apparition's glow under the activity of gamma-rays. Those who were especially keen on making jokes of this kind said that for some obscure reason they were experimenting with the radiation of only a few different liquids and trying to prove that it can be found everywhere. They questioned whether the researchers shouldn't try looking for radiation in their own hats, and so on. No little effort was required to defend this particular topic of research.

Cherenkov found that, in addition to the usual lumines-

cence of uranyl salts, there existed another extremely weak glow of the solvents themselves. It was blue in colour, and its energy increased with the movement in the direction of the short waves. As far back as 1929 Vavilov had discovered the phenomenon of universal blue luminescence, which was observed in pure solvents of diverse nature. The spectral composition of the radiation in all cases was the same. The appearance of this particular glow was connected with the presence of infinitesimal quantity of an activator that imparts luminescence even to pure solvents. Jokingly, Vavilov called them 'puny bacteria'.

It would have been natural then to draw a parallel between the blue glow of liquids and the radiation discovered by Cherenkov. However, Vavilov took his time before making any conclusions. By that time he had carefully studied the luminescent properties of a large number of substances, and their most characteristic features were established. Thus, it was noticed that luminescence could be markedly quenched when certain activators are added. The increase in temperature was also accompanied by the temperature quenching of the glow. Mention has already been made about the polarization properties of luminescent substances.

Vavilov was very much interested in all the stages of the research that was carried out by Cherenkov, and often took the measurements himself. Due to the low intensity of the source of excitation—the gamma-rays (at that time no other exciters of this kind were available)—the glow was found to be very weak, which made it more difficult to take visual measurements.

In order that subjective factors could be eliminated Cherenkov took the readings with the help of an assistant. First the researchers had to become adapted to darkness over a long period of time (between one and one-and-a-half hours). This resulted in that the sensitivity of their eyes to light increased by tens of thousands of times. The readings were conducted at equal intervals of time (approximately five minutes), so that their eyes would not get too tired. Under these conditions it was possible to work continuously for not more than two-and-a-half hours.

Participating in these measurements, Vavilov did not waste a fraction of a second. He made use of the prelimi-

nary one-and-a-half-hour scheduled stay in darkness for discussing the research that was being conducted with his pupils on the other side of the closed door. After becoming adapted to the darkness, Vavilov and Cherenkov would start their painstaking measurements.

In spite of the experimental difficulties, the new type of glow was studied in detail. It was found to have some characteristic features. Under the activity of gamma-rays the glow emerged in all of the transparent liquids and solids. Its intensity, under similar conditions of excitation, was the same in all cases. The spectral composition of the radiation did not depend on the chemical nature of the radiated substance. The radiation was characterized by spacial asymmetry and was propagated only forward at a certain angle to the direction of the exciting beam of gamma-rays. In addition the radiation was polarized and predominantly followed the direction of the oscillations of the electric vector that coincided with the direction of the beam of gamma-rays.

The glow did not possess a single property relevant to luminescence. It was impossible to quench it with the most powerful quenchers, and it did not decrease when the substance was markedly heated, moreover, its polarization did not vary. The polarization properties of the glow were substantially different from those of polarized luminescence.

Vavilov came to the conclusion that the blue glow that had been discovered was not luminescence. As it became clear at a later stage, the outstanding French physicists Pierre and Marie Curie, as well as the French physicist Male had prior to that observed this kind of glow with various pure liquids that were irradiated by gamma-rays, taking it for a weak form of luminescence. It was only owing to a profound knowledge of the nature and properties of luminescence that Vavilov had avoided making this error. I. Frank wrote that Vavilov could not help laughing at the possibility of planning discoveries. He said that any discovery was always something that one could not foretell and hence was quite impossible to actually plan, but if it so happened that a discovery was unexpectedly made in the course of some experiment, then the people who were working on it were by no means there by chance.

When it became clear that the blue glow had nothing

in common with luminescence, the question concerning its nature cropped up. In a small theoretical treatise 'On the causes of the blue γ-glow of liquids', published in 1934, Vavilov advanced the idea that the glow was brought about not by the gamma-rays themselves, but by rapidly moving secondary electrons that emerge at the time they pass through the object under investigation. To substantiate this suggestion Cherenkov tried, on Vavilov's advice, to excite the glow in liquids with a beam of electrons. For this purpose he made use of the radon that had been purchased. It was placed in an ampoule with thin walls. It should be mentioned that a gramme of radon was probably the only valuable item of wealth that the Physical Institute owned in those years. The glow proved to be identical to that which was excited in the liquids by the gamma-rays.

Cherenkov also carried out other experiments substantiating the electron origin of the discovered glow. He proceeded from the assumption that the polarization of light had to be determined by the direction of the movement of electrons. By making use of the magnetic field it was possible to expect changes in the path of electrons, and consequently, in the polarization and intensity of the glow under observation. The experiments furnished a substantial amount of evidence on the marked impact of a magnetic field upon the processes that were studied, and it proved the electron nature of the new type of radiation.

As Cherenkov's scientific adviser and the one who had made a substantial contribution to setting up and organizing the whole cycle of investigations, Vavilov, being perfectly aware of the importance of the newly discovered radiation, insisted that Cherenkov should publish the results of the research under his own name. Some time later, when speaking as an official reviewer of what had already become Cherenkov's doctoral dissertation, Academician L. Mandelshtam many times mentioned the name of Vavilov. In particular he said, 'The role of Sergei Ivanovich in the discovery of the effect is such that it should be mentioned each time this discovery is referred to.'

Vavilov got his other student, I. Frank, also involved in the research. The latter, who worked on the theoretical aspect of the problem, hypothesized that the observed glow was caused by electrons moving in the substance under

investigation with velocities that exceeded the velocity of light in the medium (the phase velocity of light). The thus emerging electromagnetic waves lag behind the moving electrons, interfere with each other, and give rise to a conical front. On the basis of these assumptions it became possible to explain the fundamental properties of the new type of radiation.

The exact classical theory explaining these phenomena was developed by I. Tamm and I. Frank in 1937. They were to exercise all their scientific intrepidity since it seemed that they were jeopardizing the very foundations of the relativity theory. In those days the firmly rooted conviction that no electron was able to move at a velocity faster than that of light reigned supreme, and moreover, it was believed that light could not be radiated by a uniformly moving charge. No little effort was called upon to prove that these assumptions were tenable only in a vacuum, and could not be applied to the movement of electrons in a refracting medium. Tamm and Frank showed that even in the case of the uniform motion of electrons in a substance, light was bound to be radiated if the velocity of the electrons exceeded the phase velocity of light in the given medium. Thus, a simple relationship was established between the velocity of the particles responsible for the glow and the direction in which the light wave radiated by them was propagated.

It took some time for the new discovery to be acknowledged as such. There were quite a few scientists, including Academician A. Ioffe, who failed to appreciate its significance at once. Frank recalled the words of one famous physicist who made the following pronouncement, 'The Lebedev Physical Institute studies the glow of some kind of filth.' All this boiled down to that in 1937 the international scientific periodical *Nature* refused to publish Cherenkov's article, which was presented by Vavilov and which was devoted to a contrastive analysis of his own experimental results and the theory elaborated by Tamm and Frank. It took more than a year to make the sceptics recognize that they had been 'in the wrong'. In 1946, 'for the discovery and the research into the radiation of electrons during their motion in a substance with a velocity exceeding that of light', S. Vavilov, P. Cherenkov, I. Frank and I. Tamm were awarded the USSR State Prize.

In 1958, I. Tamm, I. Frank and P. Cherenkov received the Nobel Prize in physics 'for the discovery and interpretation of the Vavilov-Cherenkov effect'. According to the rules, the Nobel Prize cannot be awarded to anyone posthumously, for which reason the name of S.I. Vavilov was not on the list. However, the discovered radiation is by right referred to as Vavilov-Cherenkov radiation.

Academician Cherenkov wrote, 'The results of all the efforts on the part of Sergei Ivanovich Vavilov became one of the principal foundations of the contemporary study of luminescence, and it was this particular basis that gave rise to one of the most significant findings in modern physics, viz. the discovery of the radiation of particles with a velocity greater than that of light. Without dwelling on the details of this discovery, I should like to say that it could be realized only at a scientific school of the type that was headed by Vavilov, where the basic features of luminescence had been studied and determined, and where rigid criteria distinguishing luminescence from other types of radiation had been elaborated. It is not surprising then that even in such a prominent school of physicists as the one in Paris they remained ignorant of this phenomenon, and took it for nothing more than ordinary luminescence. I am placing special emphasis on this circumstance because in my opinion it most conspicuously does justice to the outstanding role that S. Vavilov played in the discovery of the new effect.'

The discovery of Vavilov-Cherenkov radiation gave rise to the new branch of contemporary physics that studies the electrodynamics of moving sources of light in a refracting medium with a velocity greater than that of light (relativistic velocity). The most singular properties of Vavilov-Cherenkov radiation are at present widely used in determining the presence of various types of high-energy elementary particles, and in investigating the properties of such particles. In particular, the velocity of high-energy particles can be established by the angular distribution of Vavilov-Cherenkov radiation with a degree of accuracy as high as 0.1 percent.

Special counters of elementary particles (Cherenkov counter) have been developed, where photoelectron multipliers are used as light detectors. These counters function by registering Vavilov-Cherenkov radiation. According to the presence and the character of this radiation, it

becomes possible to discover not only the presence of elementary particles and to determine their velocity with a high degree of precision, but also to establish their nature and find out whether their radiation is brought about by electrons, positrons, protons, or other elementary particles.

The study of Vavilov-Cherenkov radiation has led to a number of outstanding discoveries. Thus, between 1955 and 1956 it led to the discovery of new elementary particles, viz. antiproton and antineutron, the first particles of antimatter received in terrestrial conditions.

Cherenkov counters are widely employed in the research on cosmic rays—the fluxes of high-speed elementary particles produced by the cosmic radiation in the Earth's atmosphere. The counters are installed on satellites and space rockets. Special kinds of Cherenkov spectrometers have been developed which make it possible to determine the energy of gamma-rays with a high degree of accuracy and over a wide range when experiments are conducted with various types of accelerators. Vavilov-Cherenkov radiation is used for the generation of millimetre radio waves, in the creation of controlled thermonuclear reactions, in a series of highly important problems in astrophysics, etc.

The Vavilov-Cherenkov radiation is widely spread in nature. On the one hand, it is necessary to take it into consideration when studying various natural processes and phenomena, and on the other, it is employed on a wide scale in the solution of a large number of important problems that the physical sciences have to cope with. Nowadays there is hardly a single physicist who is not aware of how enormous the significance of this discovery is.

THE HOLY WAR

On June 22, 1941 the peaceful labour of the Soviet people was interrupted by the treacherous attack of Hitlerite Germany. The Great Patriotic War began. The next day a meeting of the Presidium of the USSR Academy of Sciences was held, which decided how to restructure the Academy's activities so that they would serve the military purposes. With the aim of preserving scientific personnel and material assets and of not losing time in undertaking urgent research, a large number of academic

institutes were transferred to the remote rear of the country. At the end of July 1941, the State Optics Institute was evacuated to Ioshkar-Ola, and the Lebedev Physical Institute of the USSR Academy of Sciences moved to Kazan. Sergei Vavilov continued to be in charge of the two institutes.

In Leningrad, a group of researchers from the State Optics Institute remained. In spite of cold and hunger it developed the projects that were most necessary at that time: measures were taken to repair and bring up to date various types of range finders for anti-aircraft defence, methods were elaborated to control camouflage coatings as well as those to control the camouflage of warships, special kinds of goggles for pilots manufactured and mirror periscope rifles used by snipers were produced, photographic cameras for submarines were repaired, etc. In those days in Moscow, in the building of the Lebedev Physical Institute of the USSR Academy of Sciences, a small plant that provided the Front with what was required began to function.

A special train ran to evacuate the employees of the State Optics Institute. Forty freight cars were allotted for that purpose. When the staff arrived in Ioshkar-Ola they themselves moved the property of the Institute to Sovetskaya Street, into the yard of a new three-storeyed building of the Forestry Institute, which was temporarily made available for the use by the State Optics Institute.

The building was in no way fit to serve the purposes of a research institute. Thus people from the State Optics Institute immediately began to rebuild it. The bi-illumined hall was divided into smaller compartments with rough planks of wood functioning as their walls. In their turn these small rooms were further partitioned into booths, with the wiring temporarily installed along the walls. While the construction was in progress the equipment and the library remained in the yard. When the rainy season began, the Institute people had to dry every single book and instrument. On the ground floor Vavilov was allotted a special space for his own study.

Vavilov was himself in charge of the evacuation of the Physical Institute. He gave orders as to what should be taken, how it should be packed, etc. He insisted that the Institute's large library should be transferred to Kazan. It was well taken care of and widely used by all the

members of the Academy's institutes who at that time were staying in Kazan.

The evacuated institutes were accommodated in the building of Kazan University. The University's small physics building was to provide space for three institutes: the ground floor went to the Institute of Physical Problems, the first floor was allotted to the Leningrad Physico-Technical Institute, and the Lebedev Physical Institute of the USSR Academy of Sciences was given the set of rooms where the physics practicum had prior to that been conducted. Seventy-seven members of the Institute had to carry on their research in the ten rooms that were very much pressed for space, with the library collection covering the walls of the corridor. In spite of all the difficulties as early as August 1941, the Institute had started to function in full force.

Space was severely limited and there was not enough equipment nor materials. Electricity and water were supplied intermittently, to say nothing of the fact that there was no gas at all. The living space was densely populated, and people were constantly experiencing a lack of food and fuel. However, everyone understood that a life-and-death struggle was going on and that it was on its outcome that the fate of their country depended. No one complained, instead they worked up to ten hours a day to do all that was possible to have victory day arrive sooner.

In Ioshkar-Ola Vavilov and his wife first lived in a small wooden house in Volkov Street, and then moved to a three-storeyed stone building in Komsomolskaya Street where the State Optics Institute's hostel was then situated. Vavilov's son was at the Front with those who were defending Leningrad at the time. The Vavilov's neighbour turned out to be Academician A. Terenin.

It was in the years of the war that Vavilov's managerial talent found its particularly coherent expression. In the article 'At a New Stage', which was printed in the wall newspaper of the State Optics Institute in the autumn of 1941, he wrote, 'We have received ample opportunity to continue our work in quite new conditions, and no special proof or instructions are required to tell us that our efforts must be directed entirely to help the Red Army... We have reconsidered our research plans and shall continue doing so in compliance with the circumstances, taking every

single opportunity to make sure it corresponds to the solution of most urgent demands... But the reconsideration of our plan is not all. It is the duty of everyone of us to begin working in new conditions without a moment of delay, to increase the volume of what we produce, its quality, and the intensiveness with which the work is to be done. The situation is such that in these new conditions we are supposed to now and then take upon ourselves the functions of porters, carpenters, foremen, and it should be quite clear to all of us that this work is honourable work since it is bound to speed up the opening of our Institute, and consequently help the Front... This is something we should bear in mind every single day irrespective of what the established plans may be.'

To speed up the research Vavilov made use of not only his own people, but also of the permanent inhabitants of that city. Thus, it was on his initiative that the Lebedev Physical Institute of the Academy of Sciences availed itself of the help that came from the laboratory of the Kazan chemist Academician Aleksandr Arbuzov.

Vavilov not only directed the investigations at the State Optics Institute, but also directly participated in many of them. This resulted in that the army, in addition to what was mentioned before, received new models of stereoscopic telescopes and various lenses for aerophotography. Moreover, blackout methods were elaborated and norms of the admissible illumination of objects in ordinary conditions and at the time of air-raid alerts were established. These methods were widely employed in the illumination of the quays on the Volga River, which served as a particularly important strategic passage for the transportation of military freight. Special devices presupposing the use of permanent phosphors were produced, they made it possible for the artillery to carry on aimed fire at night. Light signals for photographic systems were also designed.

New methods of spectral analysis were elaborated, new types of optical glass were created, methods used in luminescence studies were worked out, and instruments for the exploration of solonetz oils were designed. Vavilov insisted that the prewar work on developing electronic microscopes should be continued.

On Vavilov's initiative the Lebedev Physical Institute was producing permanent phosphors that were to be

applied to the scales of instruments and primarily to those installed on planes. These instruments were invaluable at the time of night flights. The production of a small series of experimental luminescent lamps for submarines was also properly organized. S. Vavilov, V. Levshin, B. Vul and S. Fridman visited a school where tankmen were trained in order to find out their requirements. This resulted in that phosphors were made that produced a light flash under the activity of infra-red rays. They were tested in 1943 with success and were further employed for night vision and signalling purposes.

The Lebedev Physical Institute worked out a luminescent method for the exploration of mineral resources, research was conducted on the express spectrum analysis of ferrous and non-ferrous metals and the production of spectral instruments known as metallurgical spar spectroscopes, or steeloscopes. The thickness gauge, functioning with the help of gamma-rays, was a new instrument that was created and introduced into practice. Miniature radio loop aerials with permalloy cores were designed, together with acoustic trawls and many other things.

In his reminiscences of the difficult years of war that the Lebedev Physical Institute lived through, Vavilov wrote, 'Quite on its own the laboratory changed its research topics so as to help the Red Army, the military industry, and the hospitals. The outcome was indisputably felt. The Institute helped to initiate the production of permanent luminous compounds. The staff of the institute learned to prepare ceramic materials for the insulation of radio-capacitors—an activity that later became the concern of enterprises that now produce tens of thousands of them every month, the laboratories of the atomic nucleus provided plants with new flaw-detectors, the hospitals received new X-ray stereo-instruments from the Lebedev Physical Institute, people doing acoustics at the Institute worked at the Front, fulfilling very important military assignments, the theoreticians helped with their calculations in the battle with magnetic and acoustic mines, while the specialists in luminescence discovered new effective means of utilizing luminescence to solve military problems, thus bringing together the novelties in physics with what was required for military purposes. The work that was done at the Institute in the field of spectral analysis and that found

its expression in newly elaborated methods and instruments found its way into the plant laboratories and spread throughout the plants with no loss of time. The navy and air force received new methods from the specialists in oscillations. The library of the Physical Institute was the only academic library that was almost wholly evacuated and made available to all academic institutions. The role it played in the work of the Academy in Kazan could hardly be overestimated.'

Anton Sevchenko, one of Vavilov's closest students and colleagues, told the author of this book that Vavilov never stopped thinking of the fate of his elder brother Nikolai, who had been arrested shortly before the war. In 1943 news reached him that his brother had died. With this tragic event weighing heavily upon him, Sergei Vavilov wrote a letter to Stalin, in which he expressed his irrefutable conviction in the innocence of his brother. He let Sevchenko read this letter. In ten days' time Vavilov was ordered to fly immediately to Moscow. A. Sevchenko and B. Sveshnikov came to see him off at the airport. They were all very much depressed.

Vavilov was away for five days. When he came back, he said that he had been received by Stalin, who assured him that he knew nothing about his brother's fate and that he would look into this matter. He also told Vavilov that he trusted him implicitly. Vavilov was instantly appointed representative of the State Committee for Defence. A special body responsible for the coordination of scientific research was organized, whose function consisted in forming the closest possible ties with the military establishment.

Many new problems cropped up for Vavilov. He now not only had to commute between Ioshkar-Ola and Kazan, but also to take train to Moscow. During the war this presented no minor difficulties. Moreover, Vavilov's health was getting worse. It was very hard to keep up with this kind of rhythm, but he never complained of his fate, remaining invariably smart and self-possessed.

Academician A. Lebedev wrote, 'What produced a great impression upon all of us was the perseverance with which, in the period of the Great Patriotic War, he made his frequent train trips from Kazan, where the Lebedev Physical Institute was situated, to the Optics Institute in Ioshkar-Ola. Nothing could stop him from travelling

in those overcrowded carriages where not infrequently one had to remain on his feet all night long after having become totally exhausted waiting for the train, which did not run according to schedule and stayed motionless for hours on end at some stations or between them so as to get enough steam. It was surprising to see a man who looked so frail possess the will-power that could be compared with that of our heroic soldiers who were making their last stand in the face of the enemy, thus defending their Motherland. I remember the trips we took together to Moscow. They were to fulfil the assignments of the State Committee for Defence. Each journey was a problem. It was difficult to get from one place to another in Moscow and very often Sergei Ivanovich came home completely exhausted, feeling at such moments, as he used to say, that he was more dead than alive. However, he hever complained, and continued to do his duty. I always wondered how his well-wishingness and consideration for the needs of those around him could go together with the harsh and pitiless attitude towards himself. There was no question of sparing oneself when it came to fulfilling what he considered to be his duty. In everything that was of importance he never deviated from the path that he regarded as the true one.

Professor B. Nepoient of the State Optics Institute told the author of this book that the train running from Ioshkar-Ola to Kazan, with wooden logs serving as its fuel, covered the one-hundred-and-forty-kilometre distance in twelve hours. The carriages were overcrowded and there was practically no air to breathe. This made Vavilov feel as if he were suffocating, thus forcing him to stand at the cold end of the corridor in the dense crowd of passengers from the moment he got on the train till it reached the terminus. During one of such journeys he caught a severe cold which developed into pneumonia. Things were made easier for Vavilov, when at the end of the war the State Optics Institute was allotted a special compartment on such trains.

In Kazan Vavilov had a small room, where he stayed together with Lebedev each time he came to the Physical Institute which sometimes was twice a week. Zinaida Morgenshtern, one of Vavilov's colleagues, recalled that Vavilov's contacts with the Institute people were never purely formal. Quite the contrary, there were talks after

which everyone felt encouraged to put in more work and became more fully aware that his or her work was exactly what was required.

Vavilov possessed the wonderful gift of inspiring people. Morgenshtern was deeply moved to witness his unreserved and friendly attitude to his colleagues. One evening when the whole luminescence laboratory decided to go to the cinema, a woman working in the laboratory entered Vavilov's office, took his arm, and asked him to join them. Vavilov accepted the invitation with great pleasure. This did not surprise anyone: the director of the Institute was regarded as being on a par with all the others.

In 1943 something occurred in Ioshkar-Ola that nearly cost Vavilov his life. His son Viktor had come to visit his parents from the Front. In the evening both father and son were talking at the table when all of a sudden a shot was heard. The window of their room was naturally lit. The bullet had been fired from outside. It flew between their heads barely missing them.

The transgressors were apprehended immediately. They were two boys who had managed to get bullets from a rifle, had made their own pistol, and decided to do nothing better than to fire at a lit window. In spite of the fact that the two offenders were not yet of age they were to be severely punished in accordance with the laws of the war period. Vavilov took great efforts to see that the two little hooligans were not charged.

The four members of our family had also been evacuated together with the Physical Institute to Kazan, where we were put up in a room twenty square metres in size, in an old small two-storeyed house lacking in any amenities. The room we lived in served the purposes of a bedroom, dining-room, kitchen and a place for keeping firewood.

Vavilov came to see us frequently. We always did our best to make the room look more or less decent on such occasions, though it was next to impossible to do so. However, all our embarrassment vanished and no one thought of the humbleness of the surroundings in the presence of the man whose open-heartedness left no room for conventionalities.

What remained particularly indelible on my memory is the last time Vavilov came to visit our temporary abode in 1943. When he stepped over the threshold, he seemed

to have taken up all the space in the room. He was wearing a suit of light colour which he had since the prewar days and which made him look very smart. It was the time when the battle at Kursk was in its initial stage. I did not grasp everything that Vavilov and my father were talking about, I was then only in my seventh year at school. But what I do remember very clearly were Sergei Vavilov's words, every one of which rang with adamant conviction that the Red Army would soon crush the Fascists and that it was high time measures were taken to prepare the return of the Lebedev Physical Institute to Moscow, which we had all been missing so much.

In autumn Vavilov managed to get permission for the Lebedev Physical Institute of the Academy of Sciences to be moved to the capital. In May 1945 the State Optics Institute also returned to Leningrad. Both these Institutes and their scientific adviser had honorably passed through the rigorous trials with which they were confronted during the war.

On their return home, the staff of the Physical Institute found their building in a highly neglected state. The linoleum that once covered the floors had been torn off, and in those years the purchase of a new one presented no minor problem. The 220th anniversary of the USSR Academy of Sciences was in the offing. It had been decided to give it due credit, though one could hardly imagine foreign guests coming to the Institute which was 'floored for want of a flooring', as Vavilov joked rather sadly. His efforts however were crowned with success and the Physial Institute managed to get the parquet.

When Vavilov came back to Moscow, he immediately tried to reestablish contacts between the Physical Institute and the Physics Faculty of Moscow State University. In spite of his numerous commitments, he willingly agreed to work as professor at the Optics Department of the University without receiving any renumeration for his service. He supervised the work of several students doing their graduation papers and gave a number of reports on the theory of radiation at the University.

Summing up the war period, Vavilov wrote, 'The whole scientific bulk of the Academy—from Academician to laboratory assistant and mechanic—did not lose a fraction of a second to direct all their efforts, knowledge and skill towards helping the Front in every possible way.

The theoretical physicists took up the problems of ballistics, war acoustics, radio and many other fields rather than continuing their research on intranuclear forces and quantum electrodynamics. The experimentalists, laying aside, for the time being, the most vital problems of cosmic radiation, spectroscopy and others, concerned themselves entirely with flaw detection, spectral analysis for the factories, magnetic and acoustic mines, and radiolocation. Specialized military research institutes, factory laboratories, shops and the Front itself had most tangibly felt the true and rigorous impact of scientific thought that was pivoted within the walls of the Academy. In a large number of cases the physicists worked directly at the Front, testing what was suggested by them in action. Many physicists had given up their lives on the battlefield, defending their Motherland.'

In 1945, when speaking before his electors at one of the Leningrad factories, Vavilov had every right to say that he was one of the great army of scientists whose activity had markedly helped the Red Army to win the war.

In 1948 Sergei Vavilov was awarded the Order of Lenin 'for the successful work on the development of the country's optics and mechanics industry, the fulfilment of the government's assignments on the elaboration of new models of optical instruments and the scientific achievements in optics'. In that same year he received an honorary diploma from the Supreme Soviet of the Mari ASSR for his work during the war. As has already been mentioned, it was also then that he was awarded the USSR State Prize for his research on luminescence and the studies on the quantum fluctuations of light.

AT THE HEAD OF SOVIET SCIENCES

In the prewar period the studies in luminescence had become so vast in scope that their coordination had become imperative. It was decided to convene the First All-Union Conference on Luminescence, which was scheduled for June 1941. This however was prevented by the war. But as soon as Vavilov and Levshin returned to Moscow, they started making all the necessary preparations for it.

In October 1944 Moscow saw the opening of the First All-Union Conference on Luminescence. It was attended by more than three hundred scientific workers, represent-

ing one hundred and thirty scientific and educational institutions and industrial establishments. Among the participants were five Academicians, three Corresponding Members of the USSR Academy of Sciences, thirty-four Doctors and sixty Candidates of Sciences.

The sessions were held at the Lebedev Physical Institute of the USSR Academy of Sciences with Sergei Vavilov in the Chair. The conference hall was illumined by a chandelier with luminescent lamps that had been produced specially for the occasion, and chains of the same lamps ornamented the walls.

Vavilov made a grand opening speech in which he outlined the principles relevant to the problems in luminescence. In it he formulated the very concept of luminescence which had been universally acknowledged for a long time. According to Vavilov luminescence was defined as an excess over the temperature radiation of a body when the excessive radiation is characterized by a finite duration equal to or more than 10^{-10} s. The stipulation of the finite duration of the afterglow made it possible to distinguish luminescence from diffused and reflected light, bremsstrahlung of electrons, Vavilov-Cherenkov radiation, etc.

In 1969 Levshin produced further evidence that the data obtained after the death of Sergei Vavilov revealed the complexity of the phenomena of luminescence and that its definition called for additional elaboration and refinement. However, it must be mentioned that Vavilov's definition has to this day preserved its significance, serving as a guide to a more profound understanding of physical processes, primarily those of relaxation occurring in luminescing systems.

At the conference Vavilov also gave a problem report entitled, 'Concerning the luminescence of solutions', in which he summed up the research carried out by Soviet physicists and set before the country's science the task solving the most important problems in the physics of light. The Conference revealed the rapid development of research in luminescence in the USSR and the leading role of Soviet scientists in this particular field. It was decided that the organization of a unified centre for the coordination of luminescence research conducted in the Soviet Union was essential.

In December 1944 a luminescence commission was formed

at the Lebedev Physical Institute, which in September 1945 was put under the jurisdiction of the Physics and Mathematics Department of the USSR Academy of Sciences. Sergei Vavilov was appointed its chairman and his deputy was V. Levshin. The commission included prominent scientists working in luminescence as well as representatives of industry. Vavilov was at the head of this commission till the end of his days when he was succeeded by V. Levshin, who held this post for eighteen years. In 1957 the commission received the status of a scientific council on 'Luminescence and Its Implementations in the National Economy'. On the death of V. Levshin in 1969 it functioned under the direction of M. Galanin, a Corresponding Member of the USSR Academy of Sciences and also one of Sergei Vavilov's former students.

Five weeks after the Great Patriotic War was over the Soviet people were celebrating the two hundred and twentieth anniversary of the USSR Academy of Sciences with due reverence. This fact did not remain heedless on the part of the scientific world. Theodor Svedberg, the Swedish professor of physics and chemistry and Nobel Prize winner, wrote, 'The most remarkable thing was that the Russians were the first nation to organize an international congress of scientists after the war.'

A special jubilee commission was organized to celebrate the event. It was headed by Komarov, the President of the USSR Academy of Sciences, with Vavilov as one of its members. The Presidium of the Academy convened a jubilee session, the opening of which was held at the Bolshoy Theatre in Moscow on June 16, 1945. It was attended by more than one thousand two hundred people. Besides the representatives of Soviet science, prominent scientists from sixteen other countries (Belgium, Bulgaria, China, Czechoslovakia, Finland, France, Great Britain, Hungary, India, Iran, Yugoslavia, Mongolia, Poland, Roumania, Sweden, and the USA) were also present.

The sessions were first held in Moscow, where reports were given on the achievements of the USSR Academy of Sciences in various fields of knowledge. The celebrations were then continued in Leningrad, the city where the Academy had been founded by order of Peter I. On June 23 the session concluded its work in Moscow.

The Lebedev Physical Institute may well be regarded as the Academy's contemporary since it originated within what would now be called a physics study of the St. Petersburg Academy at its very outset.

In connection with the jubilee, about fifteen hundred members of the Academy, whose work was regarded as exceptional were awarded various tokens of appreciation by the government. Vavilov received the second Order of Lenin for his outstanding service in the development of science and technology and in commemoration of the 220th anniversary of the USSR Academy of Sciences.

Soon the question of electing a new president of the Academy arose. At the time V. Komarov, who was seventy-six years old, held the post. I. Frank recalled the following: 'Sergei Ivanovich's predecessor as President of the USSR Academy of Sciences was Academician Vladimir Komarov, a very prominent scientist. His health had for a long time been very poor, and his presidential power was gradually slipping away from him, while the assuredness of some of the bureaucrats that they could actually administer scientific matters, which is customary in such cases, was taking the upper hand. The standing joke (based on a phonetic effect) was that the Academy was governed by a camarilla rather than by Komarov himself. It was quite natural then that this kind of situation could not be endured any longer.'

A. Sevchenko told the author that in May 1945 Vavilov was summoned to Moscow. He thought that he would be asked to discuss the planned visit to Karl Zeiss's optical plant in Jena. However, instead he was offered the presidency of the Academy. It was so unexpected that at first he refused, though later he did give his consent.

On July 17, 1945 the general meeting of the Academy of Sciences was presented with Academician V. Komarov's letter requesting to relieve him of his duties as president of the Academy because of illness. He recommended Academician S. Vavilov to succeed him in this capacity. Komarov's request was complied with accordingly and the meeting opened the discussion of the candidature for the new president, which was supported by thirty prominent Academicians of various fields of research.

Nikolai Bruevich, Academician-Secretary of the USSR

Academy of Sciences, announced that approval of Vavilov's candidature had come from all the departments of the academy and from a large number of Academy institutes. With ninety two out of ninety four votes in his favour Sergei Vavilov was elected President of the Academy.

Ivan Bardin, the vice-president of the USSR Academy of Sciences, wrote that Vavilov was the only candidate for that post since he was not only the generally recognized scientific authority of world renown, but also a scientist with a vast experience of organizing scientific research. In addition, he was a virtually outstanding representative of physics which in those days was gaining ever more ground in the foremost ranks of the sciences. If, in addition to this, we were to take into consideration Vavilov's unusually wide range of ideas, enormous erudition and the indefatigable desire to actively promote his country's cultural development, we would not find it difficult then to fully appreciate the opinion expressed by Academician I. Bardin.

Deeply moved by the confidence of his colleagues Vavilov stated, 'Vladimir Leontyevich has passed on his duties to me at the moment when the Academy is at the outset of a new and highly important period in its history. The great victory on the battle-fields has made it imperative for us to make new advances in culture and technology. This is what our own people desire and what the whole world expects of us. To accomplish this honourable task we must mobilize every single scientific potential that we have at the Academy. We shall have to create new and more favourable conditions so as to best utilize this potential. We shall also have to do much work to train new specialists and to propagate a genuinely great and original culture throughout the numerous centres of our vast Motherland... Taking upon myself this extremely difficult responsibility I cannot but wholly rely on your continuous help. I derive my assurance of success from the awareness of the fact that the Academy of Sciences enjoys the unfaltering support of our Soviet government and the Party.'

Professor E. Shpolsky told the author of this book that he had visited Vavilov on the day he was elected president. He found him in an elevated mood, with a great desire to work and full of plans. At the same time, listening to endless greetings, Vavilov never stopped repeat-

ing, 'But this is no occasion to be congratulated on.' He understood only too well, and more than anyone else, the enormous responsibility that was now weighing upon him.

Vavilov's election was enthusiastically received by everyone at the Lebedev Physical Institute. A meeting was instantly organized at which its members warmly greeted the new president. One of those who took the floor was an old worker who was called Uncle Kuzya at the Institute. He shook hands with Vavilov and said, 'My dear Sergei Ivanovich, you will truly be a president of the workers and peasants.'

Soon it became quite clear that the choice had been most propitious. The new president not only perfectly understood what was required for further progress in the natural sciences, but was also remarkably competent in those problems concerning the humanities. This enabled him to correctly assess each particular situation and render his support to those currently important trends in the sciences that required it most urgently.

Vavilov moved from Leningrad to Moscow and left his post of director of the State Optics Institute to Academician A. Terenin. However, the luminescence laboratory at the Institute remained in his charge and once or twice a month he used to come to Leningrad for several days to see how the work was going and to meet the Institute people. P. Feofilov wrote, 'The general impression was that each time Vavilov returned to the familiar atmosphere of the Optics Institute, his friends, colleagues and pupils, he actually enjoyed a brief respite from the arduous responsibilities that he had in Moscow.'

Immediately after the war Vavilov was appointed Chairman of the commission that ascertained the losses that the country had sustained owing to the fascists. He now had to acquaint himself with the horrifying documents that revived before his very eyes the dreadful events of the war, which had only recently ended. This was indeed an onerous job since he could not but take to heart everything that stood so vividly before his eyes.

New problems of unprecedented scope had arisen in science. The Soviet scientists had to solve the most important problem of catching up with the researchers in other countries and also had to surpass them in the shortest possible period of time. To achieve this it was

necessary to join the efforts of all the Soviet scientists and to organize the research conducted in the scientific institutions in accordance with a unified and well thought out plan.

In this gigantic organizational work, the main role was attributed to the president of the Academy. It was precisely with him that the principal responsibility for the correct choice of scientific policy rested, and this policy had to take into account the needs of the country as well as the peculiarities and advantages of Soviet science.

In 1946 Vavilov wrote, 'Soviet science is not merely a part of world science that has developed within the territorial confines of the USSR. It is a science with an essentially unique system and character... The great victory of the proletariat in October 1917 paved the way for the construction of a new socialist society firmly rooted in an advanced scientific foundation. The political power of our State is now in the hands of the working class and its vanguard—the Communist Party... Science has become a necessary and highly important branch of the newly organized State, which thoroughly embodies the Bolshevik Party principles.'

Vavilov pointed out that the development of the Socialist State was taking place according to the plan, which in its turn had a firm scientific basis. Science in the Soviet Union was called upon to lead support to the building of a Communist society, and for this reason it had to first and foremost take into consideration the vital needs of the country and follow the plan.

This essential principle was not immediately given due credit by all the Soviet scientists. Vavilov wrote, 'The possibility of planning our research did not at first receive all the confidence it deserved. People reasoned roughly like this: science in the main has for its task the unravelling of the unknown. How then is it possible to plan something that has not yet been discovered? Wouldn't this be the same as the task that is described in one of our folktales: 'Go there—I know not where. Bring me that—I know not what.' This reasoning is actually quite erroneous. It is refuted by the very history of science and primarily by our own Soviet experience.

The president was perfectly aware that what should be planned was the setting of the task and the methods relevant to its solution, though the results themselves

might prove to be quite unexpected. He made every possible effort to organize and implement the planning of research throughout the whole country.

Underlying Vavilov's planning of the further progress in science was the prerequisite bond between thorough theoretical research and the practical needs of the national economy. It was in the integration of theory and practice that he saw one of the greatest advantages of science in a Socialist society. He wrote that Soviet science 'combined in itself the wholesome and powerful practicality determined by the tasks involved in the building of Socialism with that inherent logic of scientific thinking that is required for the correct formulation and solution of scientific problems'. Moreover, he lay particular stress on that when planning scientific research it was necessary to get to the bottom of the phenomenon and visualize the trend of the quest rather than make *ad hoc* decisions. He was convinced that 'owing to the socialist nature of our society we could become the leaders in world science'.

Vavilov saw only too well the urgent need to change the very character of contemporary scientific research. If prior to that period a large number of investigations could be carried out by each scientist on his or her own, the time had now come when the problems had become so complicated that their successful solution in most cases required efforts on the part of large groups of scientists, including those belonging to different professions. Vavilov made it abundantly clear that as far as its content, form and purpose were concerned, science had a deeply rooted social and collective character. Any science is always the sum-total of knowledge that had been acquired by many people—the past generations and our contemporaries—and is the result of a highly complicated collective endeavour.

Taking into account the specific features of the time, Vavilov primarily encouraged the formulation of such complex problems whose solution lay at the junction of several sciences. At the same time Vavilov pointed out that progress in science was characterized by its own specific logic which one must always take into consideration: unless science yields benefit and leaves something in store it cannot possibly be regarded as functioning under normal circumstances.

The president of the Academy thoroughly analyzed the conditions relevant to the propitious development of contemporary scientific research. On March 6, 1946, when taking the floor at a meeting of scientific researchers of the Leningrad district in Moscow, he said, 'Please allow me the opportunity to formulate in a condensed form a number of conditions that are found to be absolutely essential for proper and rapid progress in science today. These conditions are the following: (1) specialists, i.e. a large number of well-trained people capable of conducting scientific research and in command of the technology used in their specific fields of study; (2) suitable and commodious institutes and laboratories, which in some cases would have specialized premises; (3) a variety of scientific equipment, a large stock and assortment of reagents and adequately provided libraries in which the world scientific literature in the given field of knowledge would be represented; (4) ancillary mechanical, fitting, glass-blowing, radio-assembling and other workshops; (5) comprehensive and timely introduction of scientific research of technological significance and the possibility of speedily publishing scientific results that contain no secret information; (6) an elaborated system of research institutions; (7) appropriate living conditions for a scientist that allow him to concentrate his entire energy and knowledge on the solution of scientific tasks.'

Vavilov did everything in his power to see to it that these conditions were realized in practice as speedily as was possible. First and foremost he focused his attention on the need to markedly enhance the training of highly qualified specialists, such as Candidates and Doctors of Science, and he substantially improved this kind of instruction. No minor importance was attributed to perfecting the instruction and training of postgraduates and those preparing their doctoral dissertations. Special emphasis was placed on the training of specialists for union and autonomous republics. In those years representatives of the country's fifty six nationalities were enrolled in postgraduate courses at the USSR Academy of Sciences.

In order that the standard of postgraduate courses could achieve a still higher quality the Presidium of the USSR Academy of Sciences elaborated a whole system of measures. The rules concerning the examinations that the postgraduates were supposed to take prior to the defence

of their dissertations were reconsidered, and the scientific advisers were made even more responsible for the quality and the supervision of the work done by the postgraduates. On Vavilov's initiative, the training of future Doctors at the Academy was reorganized. The number of researchers from provincial institutes that were given the opportunity to work on their doctoral dissertations at the central research institutes of the Academy increased. In Vavilov's opinion a Doctor of Science was someone who had founded a new scientific trend and was in a position to be at its head. If, however, the Doctor of Sciences diploma was received by a person who did not deserve it, society and the State itself were obliged to pay for it dearly.

Knowing well that progress in the most complicated scientific research was unimaginable without a firm material basis, Vavilov was anxious to see to it that new institutes were built, laboratories organized, and old establishments expanded, brought up to date, provided with modern equipment, and experimental and technical facilities made available on their premises.

The construction of a new building for the Lebedev Physical Institute was also Vavilov's idea. He became very much involved in this, considering every single detail of the project and following its progress step by step. He didn't miss a trifle. He was interested in the laboratory spaces, the rooms for auxiliary services, the libraries, and the furniture. It was also his suggestion that conference halls and many other rooms should have fluorescent lighting. Unfortunately, it was only in 1953 that the Physical Institute moved into the new building, Sergei Vavilov was not destined to work in it himself.

Vavilov did not forget Moscow University either. The Dean of its Physics Faculty, Professor V. Fursov, told the author of this book that soon after the end of the war it was decided to erect a number of monuments in Moscow, commemorating the heroic deeds of the Soviet people. A project was also put forward to build the House of Soviets in Lenin Hills. However, in Vavilov's opinion, the best monument to the postwar epoch would be the construction of the House of Science in the capital, or the new building of Moscow University. His idea was encouraged and within an incredibly short

period of time, a great architectural complex intended for the educational and scientific purposes of the University was designed and built on Lenin Hills. Vavilov was uninterruptedly involved with the construction, and tried to render all the assistance that was required for the solution of a large number of problems that emerged when the new building of the University was being built and equipped.

No less attention was paid to the construction of other scientific institutions. It was during Vavilov's lifetime that the Zelinsky Institute of Organic Chemistry, the Baikov Metallurgical Institute, the reconstruction of the Radium Institute and the building of the Pulkov, Alma-Ata, and other observatories took place. New buildings for the institutes of machine-science, mechanics, automation and telemechanics, mining, chemical physics were built, and the foundation of the Main Botanical Garden of the USSR Academy of Sciences covering a territory of over 500 hectares laid. All in all, in Vavilov's time three hundred new, large scientific objects were built and planned.

Vavilov focused particular attention on instrument engineering. He considered it intolerable that the major scientific equipment came only from abroad, and thus made every possible effort to promote the development of this branch of industry primarily in optics, in his own country.

Rapid advances in nuclear research had brought about the necessity of building gigantic machines known as particle accelerators, whose construction was undertaken in a number of scientific centres of the country. In 1946 the construction of a synchrocyclotron began at the Lebedev Physical Institute. Vavilov contributed significantly to its successful completion.

At the same time, from the reminiscences of Academician Aleksandr Mints we know that Vavilov used to assert that contemporary experimental physics too often led to the creation of extremely complicated set-ups that cost a large sum of money, while a talented physicist could choose quite a different path—the path of a subtle and elegant experiment in which the creative flight of imagination is supplemented by simple instruments that one can create with one's own hands, which leads to results that are of fundamental significance.

As an example Sergei Ivanovich cited the classical works of P. Lebedev, who himself built the instruments that were intended for his experiments on light pressure. According to Mints, there was no doubt that Vavilov acknowledged the importance of the 'industrialization' of physical experiments, though his heart was with such wizard experimentalists as P. Lebedev and R. Wood.

As was already mentioned, Vavilov attributed an important role to the practical application of scientific achievements. He wrote the following on the subject: 'Speaking of the inseparable bond between theory and practice in Soviet science what we primarily have in mind is that the scientist concerned with research problems, no matter how abstract they may seem today, should always bear in mind that the aim of science consists in meeting the demands of society, and hence he should utilize all the accessible means and make every possible effort to establish a link between his scientific achievements and their practical application.'

Vavilov himself as was mentioned earlier, was engaged in the research in a number of important areas of practical significance, and he called upon other scientists to undertake similar work. It should also be mentioned that under Vavilov the Academy of Sciences had for the first time begun long-term planning for the introduction of successful research that was of practical significance into actual practice.

Vavilov raised the question of the necessity to materially stimulate the creative initiative of scientists and to actively protect the priority of the State and the individual as far as discoveries were concerned. It was again on his initiative that the Soviet Union became the first country in the world to introduce a system presupposing the registration of scientific discoveries and the protection of the rights of their authors by the State. In addition a Committee on Inventions and Discoveries at the USSR Council of Ministers was organized. It played an exceptionally prominent role in protecting the interests of the State in the field of discoveries and inventions made in the Soviet Union.

Vavilov's role in stimulating the more promising trends in science can hardly be overestimated. It was already noted that he had a great influence on the dev-

elopment of research in the field of nuclear physics. In 1942, when the war was at its height, Vavilov put forward before the Presidium of the USSR Academy of Sciences the question concerning the vital importance of building two atomic reactors and a charged particle accelerator in the shortest possible period of time. He deemed it expedient to ask for funds to cover the required expense. His idea only found support with Academicians O. Shmidt and A. Ioffe. The other members of the Presidium did not believe that such an enterprise might prove successful. Vavilov, however, was perfectly convinced that he was right.

A. Sevchenko told the author of this book that when the Presidium turned down his request, Vavilov, who at that time was already a representative of the State Committee for Defence, addressed the request to Stalin directly. In 1943 the money was allotted and research in nuclear physics began to develop rapidly. The outstanding Soviet physicist I. Kurchatov was in charge of it. The efforts on the part of a very large body of researchers were crowned with success. They led to that the country developed its own nuclear power.

When Vavilov became President of the Academy, he continued to take an interest in the research on nuclear physics and encouraged it in every way he could. In his office at the Academy, seminars were regularly held for a narrow circle of people concerned with the problems of nuclear physics. Among those who attended them was I. Kurchatov. Professor V. Fursov, one of Vavilov's immediate colleagues, told the author of this book about one of such seminars at which the problems pertaining to the construction of a uranium-graphite reactor and the possibility of creating a chain reaction in it were discussed in minutest detail.

In 1949 a special scientific council was organized at the Academy whose task consisted in propagating the methods of nuclear physics in various branches of science and technology. The council was headed by Vavilov, with Academicians D. Skobeltsin and N. Semyonov functioning as his deputies.

As was suggested by Vavilov, a number of experiments were conducted at the Lebedev Physical Institute of the USSR Academy of Sciences under the direction of Frank. It was also on Vavilov's initiative that the production

of thick-layer photographic plates essential for research in nuclear physics was accomplished. Vavilov rendered tremendous help in training specialists and determining the subjects for research at the Physical Institute of the Latvian SSR Academy of Sciences where the nuclear reactor for research was launched and where research in the field of nuclear physics was carried out on a wide scale.

Space studies were of particular interest to Vavilov. This could well be accounted for by his work in the Commission on the study of the stratosphere, of which he had been in charge since 1933. The country in the postwar period saw the beginning of research on at first the upper layers of the atmosphere and then on outer space too. This was achieved with the help of rockets that reached an altitude of up to 100 kilometres. At the Presidium of the Academy a special commission concerned with outer space studies was organized, which included Anatoli Blagonravov, Mstislav Keldysh, Sergei Korolev, and others. Meetings at which S. Korolev and his immediate assistants were always present regularly took place in Vavilov's office with him in the Chair.

In Professor Vladimir Prokofyev's words it was the time when he was busy with the elaboration of new optical instruments that were installed on rockets and were intended for studies of the solar spectrum and the outer space. At the end of 1949, Prokofyev was asked to take part in a meeting that was devoted to these problems. It was held in president Sergei Vavilov's office, with the participation of S. Korolev, M. Keldysh, S. Vernov, A. Blagonravov and others. In the course of the discussion, Vavilov drew the attention of those present to the enormous significance of the research on the solar spectrum in outer space.

The following question arose: Who of the participants of that meeting ought to take upon himself the responsibility for the guidance of that project? Vavilov announced that he favoured M. Keldysh's candidature. Keldysh himself was not too eager to take up this work. Then Vavilov, availing himself of his presidential power, very politely and yet quite firmly said, 'I still do request that you concern yourself with all the questions in outer space studies and be in charge of them yourself...' Today, we can totally appreciate the appropriateness and farsightedness of that decision.

From what Academician S. Vernov said we know that Vavilov held S. Korolev in high esteem and invariably supported whatever the latter undertook to do. He became acquainted with Korolev as far back as 1934 when he was chairman of the Commission on the study of the stratosphere and conducted the first conference devoted to this problem. He helped Korolev many times whether in times of success or frustration. Korolev deeply respected Vavilov and was severely shocked by his death. He always remembered Vavilov with great affection. His study at the launching site Korolev decorated with the portraits of the scientists he most admired: K. Tsiolkovsky, I. Kurchatov and S. Vavilov.

A large number of studies on the upper layers of the atmosphere and outer space received the support of the President of the Academy of Sciences—Sergei Vavilov. We have been fortunate to witness the vigorous conquest of space by man and shall never forget the names of those who stood at the outset of this historic event.

Vavilov also contributed to the development of many other promising trends in science. Thus, on his own initiative research on finding ways of utilizing radioactive stable isotopes in the national economy was begun. Extensive investigations in the physics and chemistry of polymers, for which purpose in 1947 the Institute of High Molecular Compounds was organized in Leningrad, were also initiated. Science and technology began making ample use of mathematical methods and many other important initiatives were put into effect, which laid a firm foundation for the present-day achievements of Soviet science.

The president of the Academy directed the efforts of Soviet scientists towards the solution of practical tasks that stood before the national economy. Thus, in 1950 on Vavilov's advice a committee was organized at the Presidium of the USSR Academy of Sciences which was meant to assist the construction of such large postwar building sites as the Kuibyshev and Stalingrad hydroelectric stations and the Kara-Kum canal named in honour of V. I. Lenin. Vavilov headed the work of the commission and did all he could to see to it that scientists were directly involved in the construction of these unique structures.

Research in the field of genetics also did not escape

Vavilov's notice. Academician Nikolai Dubinin recalled the days when many a time he happened to meet Vavilov to discuss problems in genetics, and each time he received the full support of the president. Vavilov did much to organize the Institute of General Genetics of the USSR Academy of Sciences. He raised the question of starting the journal *Genetics*. N. Dubinin wrote that as early as 1946 Vavilov sent him a letter in which he suggested that the latter should write a book entitled *Genetics and the Evolution of Populations*. Unfortunately, all these plans were not destined to be realized in Vavilov's lifetime.

Sergei Vavilov had always been averse to the trend of dividing science into 'major' and 'minor' sciences. As early as during the war, in the newspaper of the State Optics Institute, he criticized the statements made by Academician P. Kapitsa, who supported this kind of division and in whose opinion the 'major' science should be the only concern of the institutes of the Academy. 'First and foremost it is possible to divide science into 'major' and 'minor' types *post-*, but no *ante-factum*. What may seem to be modest and specially planned scientific research proves at times to have sensational consequences *post-factum*. However, quite the opposite can also take place. For instance, research undertaken with the intention of producing something stupendous may turn out to be a complete failure... Hence, to demand [beforehand] that one type of institution concentrate on a 'major' science and another on a 'minor' science most necessarily results in a gross theoretical error which is as such in its very essence. The Optics Institute has never divided its science into major and minor varieties and in this respect serves as a most apparent experimental refutation of the classification advanced by P. Kapitsa. One and the same institute conducting research on the structure of atoms and on the elaboration of polishing pastes without actually knowing in advance which of the two enters into the so-called 'major' science: we know *post-factum* that these two types of research had actually become part of "major" science.'

The wounds inflicted by the war were not healing quickly enough. Life was still very difficult for people. Vavilov understood that in those hard times it was very important to help the scientists of whom the na-

tion itself expected the same. He suggested a project for the improvement of their living conditions. In 1946 it was decided to increase the living standard of the people of science. The salaries of those working in scientific and educational institutions were raised and the supply of foodstuffs and industrial commodities was improved. In the suburban part of Moscow a large resort district was built for the scientists, whose gratitude for all this found its expression in their selfless labour.

It was Vavilov's conviction that scientific research should be carried out on a wide scale with the active participation of not only the centre of the country, but also of the union republics. Academician Aleksandr Vinter pointed out that Vavilov himself took part in the organization of a network of branches of the USSR Academy of Sciences on the territory of the RSFSR and other union republics, including the Ural branch in Sverdlovsk, the East-Siberian one in Irkutsk, the Karelo-Finnish branch in Petrozavodsk, the Krasnoyarsk branch, and others. In the years when Vavilov was president, Academies of Sciences were organized in Azerbaijan, Kazakh, Latvian and Estonian Soviet Socialist Republics, while in Tajikistan and Turkmenia necessary measures were also undertaken to establish Academies in those republics.

Vavilov attached enormous importance to the coordination of scientific research in the country. In 1945, on his initiative a council responsible for the coordination of the scientific activity of the Academies of Sciences of the union republics began to function. Vavilov was appointed chairman of this council. In spite of the great difficulties that emerged when scientific research was planned on such a vast scale, the council proved to have an important influence on the development of scientific research in the union republics.

When taking the floor at one of the sessions of the council Vavilov said, 'Our scientists can be so well organized, work in an atmosphere of such friendliness and cooperation that it is precisely owing to the socialist nature of our society that we have every chance of becoming the foremost science in the world, and so I think that our combined efforts are exactly the source of the tremendous power we possess. This is something that does not exist in the capitalist society.'

As the person at the head of the USSR Academy of Sciences, Vavilov considered his duty to consist in setting the most important tasks before the Academies of the union republics, and in seeing to it that their researchers were immediately concerned with solving these tasks. He considered that the efforts of those working at the USSR Academy of Sciences, as well as those doing research in the Academies of the republics should be guided by a single plan and common problems, the solution of which would serve the national economy, and science and culture throughout the whole country.

He stated, 'The Academies of Sciences of the union republics should in their turn combine three elements in the work they are doing. On the one hand, it is necessary that they undertake the elaboration of major scientific problems together with the formulation on a wide scale of questions pertaining to the natural sciences, philosophy and technology, which do not lend themselves to be solved in the branch institutes and higher educational institutions. It is precisely for this purpose that the Academies of Sciences have come into existence. The second task of the Academies consists in the concentration of the best specialists in science. The rules of the USSR Academy of Sciences as well as those that function in all the Academies state that only highly qualified researchers have the right to work there. The third task of the union Academies of Sciences can find its expression in their closest link with the needs of the State, industry and agriculture, on the one hand, and with those of culture on the other. The Academies of Sciences should appropriately and concordantly bring all these three elements together: this is bound to guarantee the high quality of their scientific activity.'

Vavilov took a lively interest in the life of the union Academies, knew their needs, and rendered them various kinds of assistance. In his opinion, the work of these Academies should primarily be directed toward the study of the local natural resources of the republics and the development of national culture. He organized the review of research plans of the union Academies by the members of the USSR Academy of Sciences. On his own initiative, the council responsible for the coordination of scientific activity of the Academy of Sciences of union republics sent groups of leading scientists to these Acad-

emies with the aim of getting acquainted with their activity and rendering them practical assistance.

Vavilov was very much interested in the research carried out at the provincial higher educational institutions and research institutes. Thus, for instance, he encouraged the impressive research that was being done by the oldest professor of Odessa University, Elpidifor Kirillov, on the studies of the photoelectric effects in the silver halides and of elucidating the formation of the latent photographic image. On the recommendation of S. Vavilov, A. Ioffe, and Yu. Frenkel, E. Kirillov was conferred upon the scientific degree of Doctor of Sciences. In 1951 the research conducted by Kirillov was honoured with the USSR State Prize.

The unmixed regard for their problems and needs, as well as constant assistance, won Vavilov the high esteem of the scientists of the union republics. He was elected honorary member of the Armenian, Kazakh and Uzbek Academies. In addition, he was made a member of the Moscow Society of Naturalists.

Since 1945 Sergei Vavilov had held the post of deputy chairman of the section on physics, mathematics and astronomy of the USSR State Prize Committee (the Chairman of the section was Academician A. Ioffe), and in 1947 he also became a member of the Committee on USSR State Prizes in the field of science and technology.

In 1946 Vavilov suggested that a voluntary scientific and technical society of the instrument engineering industry should be organized. Its function consisted in uniting large bodies of engineers and researchers and directing their efforts towards the development of Soviet instrument engineering. This society was actually organized and Vavilov became its first chairman. He was at the head of the society till the very end of his life.

The society became a mass organization and proved to be a great asset to the country. In 1973, at the Sixth All-Union Congress of the society, it was named after Academician S.I. Vavilov. This was suggested by its new Chairman Professor P. Oshchepkov. The central management board of the society set up an annual competition for the best work in the field of instrument engineering. Every year on March 24—the day Sergei Vavilov was born—the jury sums up the results of each competition and awards prizes to the winners.

Sergei Vavilov was at his best when coping with the exceptionally difficult and responsible task of managing scientific matters in a country as vast as the USSR. Not one of his predecessors in the capacity of president had ever been able to become so comprehensively in command of everything for which the head of the academy was responsible. There was never a single new scientific initiative or even a measure of purely household character that could escape his notice.

Looking through the back issues of *Vestnik Academii Nauk SSSR* of those years one cannot but wonder at the variety of problems that were tackled by Vavilov. We can find here the planning of Soviet science, problems referring to the training of specialists, questions concerning the Academy's staff and budget, the history of science and its methodology, publishing activity and the building of monuments, the organization of jubilees of Soviet and foreign scientists, and all the troubles it was necessary to go through to return Leonard Euler's manuscripts from Switzerland. In addition to all this there were quite a few other things of greater and lesser importance.

In what follows we have a brief account of Vavilov's activity in the Presidium of the USSR Academy of Sciences that was given by Natalia Smirnova, one of his advisers: 'I can very well remember that in no less than several days after Sergei Ivanovich was elected president, he made every one of the personnel get together in the Conference Hall in Neskuchny, and in a speech that was both concise and precise, told those present of the tasks that were set before the Presidium and of those requirements that he, as president, would expect them to meet. In brief this amounted to the fact that he had not the slightest intention of being in office and in power entirely by himself but rather that he wished to help the administrative board as much as his proficiency and efforts would allow him to do so. And it was very soon indeed that all the members of the Presidium had become perfectly convinced that Sergei Ivanovich possessed the wonderful gift of supervising the work of individuals, large and small institutions and the Academy on the whole. In his very first talk about my own work he said, "Don't think that you will manage to write my own articles. All that you will have to do is to collect

the required material together with various references and all that, while the writing itself will be done by no one else but me".'

Academician A. Topchiev, the chief scientific secretary of the USSR Academy of Sciences, wrote that in the years when Vavilov was at the head of the Academy there was never a single more or less important initiative that he did not wholeheartedly encourage. At times it was impossible to understand how one and the same person could cope with the amount of work he had on his hands. Undoubtedly, he owed all this to his remarkable talent as a scientist and researcher, and also as a scientist and organizer, to his exclusive ability to work.

Vavilov could particularly appreciate his own time and that of others. As years went by he developed his own, or what was known as Vavilov-like, style of work. In spite of the enormous number of various commitments he was never in a hurry, and remained alien to any kind of bustle. He was averse to rushing from one business matter to another or to stopping any conversation before exhausting the subject under discussion. At the same time, he could not stand any talks that either lacked any subject matter or were useless. As was already mentioned, he was meticulously punctual, and invariably demanded the same kind of punctuality of other people.

Academician A. Mints recalled that one of the academicians had always been late for the conferences. One day Vavilov asked his adviser, Anna Stroganova, to come to his office and said to her in a voice that was meant to be heard by all those present, 'Anna Illarionovna, be so kind as to telephone and ask if his grace has woken from his slumbers. Say that we have all been here for a long time now expecting his arrival.' The tardy Academician heard of this episode and had never been late again.

Vavilov trained his colleagues to make clear-cut decisions. Professor Nikolai Sobolev, who from 1941 to 1943 was deputy director of the Lebedev Physical Institute of the USSR Academy of Sciences, told the author of this book that Vavilov had reproached him for trying to do everything himself and told him that this was impossible. The main task of the supervisor, according to Vavilov, was to give precise instructions to his subordinates

and then to check that the deadlines have been met and to review the quality of the work.

Academician S. Vernov, in his turn, said that Vavilov had been a strict administrator. He could not bear when exactly the same questions were discussed all over again. The person consulting him was obliged to have the draft solution of the question ready to be signed. If this was not the case, Vavilov considered the question to have not been properly prepared and its discussion was ceased immediately.

Vavilov had started a thick notebook with an alphabetical index. In it he used to enter the name of his visitor and make notes about the request. All this was done while the discussion itself was in progress. When the same person came to him for the second time he compared the requests and would often reproach the people if they were not consistent in dealing with the problem professionally. He tried never to write any papers himself, asking instead either his adviser, or the typist to do this, since, as he said himself, dictation helped him to concentrate and more clearly express his thoughts.

Anyone entering Vavilov's office often saw his desk crowded with heaps of scientific periodicals that he was looking through and making notes in the margin at the same time. The visitor often felt embarrassed to explain his business since Vavilov continued to be occupied with what he had been doing before. However, Vavilov reassured the person that he was listening attentively. And it was actually so, for judging by his questions and decisions it was perfectly clear that he understood the sum and substance of the problem under discussion.

G. Faerman recalled the following: 'It so happened that I would come to see him on some business. He would listen very attentively and quietly, without exhibiting any signs of impatience and in no way showing that he was eager to end the talk or hasten its progress. He would keep up the conversation, getting to the very bottom of what was said and becoming thoroughly interested in it. But if, when leaving his office and putting your hand on the door handle, you were to look back, you would see Sergei Ivanovich already writing something.' His gift for passing from one activity to

another was really remarkable. In addition one always had the impression that what he was concerned with at the moment was of primary importance for him.

Sergei Vavilov was never afraid to take upon himself any responsibility. S. Vernov recalled how after the war the expedition to study cosmic rays in different latitudes was organized. People had been preparing for it for a long time. The expedition called for no small sum of money, but the expenses had not been planned in good time. Vernov went to see Vavilov with the draft resolution to have the money allocated for that purpose. Vavilov called the man in charge of the planning and financial department, who told Vavilov that the paper was not formally ready to be signed. Vavilov did sign the document and said to him, 'I should be very much obliged to you if you gave your undivided attention to considering why what I have done is absolutely right.' He was against anything that had the slightest trace of bureaucracy, especially in those cases when the interests of science were to be endorsed.

All those who knew Vavilov were unanimous in laying particular stress on his enormous concern for the research carried out by members of the Academy who were working on subjects that were not even remotely connected with what he was doing himself. G. Faerman recalled the bitterness with which Vavilov once said to him, 'I needn't tell you how many people come to see the president of the Academy, and I often have to hear extraordinarily negative opinions of the work done by other people and their authors. Nobody, however, has come to me as yet to say something favourable about another man's work or to draw my attention to it.'

In spite of the high post he held and the power he possessed, Sergei Vavilov never raised his voice or spoke with a commanding tone. As was already mentioned, his orders, though given as advice, were complied with unhesitatingly. It was practically incredible to all those who knew him how he could combine the gentleness of a true intellectual with the firmness and unyieldingness when important decisions were to be put into effect.

Academician A. Veksler wrote that he would always remember Vavilov's unaffectedness. His direct and simple manner of addressing others irrespective of rank, scientific titles and age, together with his infallible well-wish-

ingness to people, was the most striking feature of his charismatic personality. The unimaginably vast scope of work he had could not prevent him from remaining invariably calm, affable, and equanimous with all those who came into contact with him even when he was unusually busy.

Within the whole period of his acquaintance with Vavilov, Veksler had only once seen him in a state of uncontrollable anger. It was like this. Veksler was telling the president about the construction plan for certain scientific structure for which he was responsible. Every effort was made to reduce the cost of the project in view of the possible complications that could arise during its construction by the commission that was to confirm it. Thus the trees and shrubs surrounding the structure were excluded from the plan. Vavilov, however, insisted that this item should remain in the project, which was quite reasonable in all respects.

As was expected, when the commission held its meeting, one of its members began to criticize this very item of the project in a rather facetious manner. This was the first time in his life that Veksler saw Vavilov extremely angry. Vavilov turned pale, jumped from his seat, banged his fist upon the table and shouted, 'Damn it, it was I who demanded that this item be included in the plan!' Vavilov's behaviour was so unusual that his opponent started stammering and uttering some incoherent apologies, while everyone else rushed to placate Vavilov.

Vavilov's approach to the solution of all problems was that of a statesman. He could not stand any petty meanness or trifling calculations when it came to discussing questions that were really serious. His vast experience gave him the right to believe that the money spent on what was actually required would amply cover the expenses and that it was unreasonable to disregard quality for the sake of saving on minor things.

Vavilov's attitude towards subordinates was very well expressed by Academician B. Vvedensky: 'Sergei Ivanovich's sense of humour did not desert him even in those cases when he was obliged to reprove or reprimand his subordinates. It must be mentioned that I fail to recall a single instance when Vavilov lost control of himself, and it was only on rare occasions that one

could hear him speak sharply to someone he had to rebuke. He was always able to convey his criticisms in a gentle way, and though he did not refute any objections, he nevertheless made his opponent see his own fault, as was usually the case. But as a rule Vavilov did this without being abrupt or hurting the person's feelings. If, however, the man did leave Vavilov's office frustrated, he himself was the only one who was to blame. Among Vavilov's most telling expressions were the following: "That's not right" (or "that's not exactly right"); and his well-known phrase, "You ought to be ashamed of yourself". This last remark indicated that the limits of his strictness had been reached and this was what people were afraid of most of all.'

Academician I. Frank wrote, 'He often began his requests with the words, "I know how busy you are, but..." and so on. This was not a mere token of politeness. Presumably, he simply had two standards: the lenient one was meant for everyone else, while that lacking in any degree of pity was reserved entirely for himself.'

Vavilov's merciless attitude towards himself and his health was noticed by many. He devoted his whole life entirely to science, ignoring the fact that he was working himself to the bone. G. Faerman said on one occasion, 'It was not infrequently that I heard Sergei Ivanovich give his opinion on the scientific books and articles that he read during his night train journeys from Leningrad to Moscow and back to Leningrad. This kind of selfless activity, with himself as an example, had a far greater effect upon others than a commanding voice or a strict order. By watching how Vavilov worked it was impossible for others to have a superficial attitude to their work.'

According to Lebedev, 'Sergei Ivanovich wholly deserved the words he once stated himself on quite a different occasion, "The world itself rests upon people like these".'

In spite of the enormous amount of work he was doing, Vavilov never neglected his duties of a deputy. In 1935, as was already mentioned, he was elected a member of the Leningrad City Soviet of Working People's Deputies. And in 1938 one could see in the streets of Leningrad a poster with the slogan 'Working people of the Vasilyevsky Island constituency! Vote for the celebrated Soviet scientist, the non-Party Bolshevik Academician

Sergei Vavilov!'. Vavilov was nominated to the RSFSR Supreme Soviet by the electorate of that part of the city in which a large number of higher educational institutions and research institutes were concentrated. In 1946 Vavilov was elected a deputy of the Supreme Soviet of the USSR representing the Lenin district in Moscow, and in 1947 he became a deputy of the Moscow City Soviet of Working People's Deputies.

He took pride in his deputy's badge and regarded the duties of the post with great responsibility and full awareness of how important they were. In a speech he made before his electorate in 1946 he said, 'A deputy-scientist, as well as the rest of the deputies, should serve his people in all their needs, ranging from the everyday difficulties experienced by an individual to matters of great significance for the State as a whole. But at the same time the deputy-scientist should be particularly concerned with the development of his own country's science and technology, the training of new young specialists, and the propagation of popular knowledge by means of schools, books, journals, lectures and the radio. He has to take measures directed at building new scientific centres, institutes, laboratories, and at improving their quality and must serve to implement the results of scientific research. It is his duty to take care of those working in science, to assist them with their scientific initiatives and innovations, and to see to it that their living conditions are improved. Lastly, he is obliged never to forget about the role of Soviet science and about the need for continuous progress and development to reach the foremost ranks of world science and technology... I think that if our deputy-scientist primarily and constantly bears in mind the service of science to the State, and if he is a good scientist, teacher and organizer of research himself, then he will prove to be quite a good deputy.'

Vavilov himself was exactly this kind of deputy. In the days of peace and during the war he had always been in the foremost ranks of those who supported the interests of science, the State and the people.

Vavilov was extremely considerate to the needs and requirements of his electorate. Thousands of people used to come to see him with the most wide-ranging questions and invariably received his help. In performing his duties

as a deputy for a period of fifteen years Vavilov virtually served his people in the true sense of that word. His adviser N. Smirnova wrote that his attitude to his responsibilities of a deputy had never been purely formal.

Regularly, twice a month, he received the electors. On such days a representative of the district executive committee was always present. While listening to what his visitors had to say, he would take notes on their requests and then he would see to it that things were progressing in each particular case. Sometimes Vavilov jokingly said to Smirnova: 'Again they have written a pitiful letter, do you think it will help?' He would sign the paper, which often brought favourable results even when the requests concerned obtaining lodgings. Those were very hard times: the country was beginning to restore its destroyed economy, and the housing problem was exceptionally acute.

Sergei Vavilov actively responded to all the most important problems of the day. He was an indefatigable fighter for peace and international cooperation. He wrote, 'Science is a two-edged and most powerful sword, which, depending in whose hands it is, can bring people either happiness and well-being, or destroy them completely.'

In his writings we can also find the following words, 'The duty that rests with the conscience and honour of scientists and intellectuals in general consists in taking all possible measures to prevent the capitalists from obligating science to serve the purpose of war against the free democratic countries. The unity of scientists in their pursuit of noble and great aims—to put an end to the employment of science in launching new wars—is one of the most significant instruments in world politics.'

In 1950 Vavilov was elected a member of the presidium of the Soviet Peace Committee. His voice was heard at the Moscow Congress of the Supporters of Peace, where he furiously denounced the war mongers. On Vavilov's initiative a group of leading Soviet scientists sent a letter of protest to the Security Council of the United Nations Organization against the American aggression in Korea. The Soviet scientists led by Vavilov came up with a sharp accusation directed at those who persecuted the outstanding French physicist Frederick Joliot Curie for his activity in support of peace and for the speech

he had made at the 12th Congress of the French Communist Party where he had declared, 'If tomorrow it is demanded of us to work for war and produce atom bombs, we shall answer only in the negative!'

Throughout the whole period of his presidential office Sergei Vavilov did everything possible to develop business contacts and friendship ties with foreign scientists. His name is widely known outside his own country. He kept in touch with a large number of scientific institutions abroad.

Vavilov's scientific merits received acknowledgement in many countries of the world. He was elected an honorary member of the Bulgarian Academy of Sciences (1947), the Scientific Committee of the Mongolian People's Republic (1947), the Polish Academy of Sciences (1950); he was elected a corresponding member of the Academy of Sciences of India (1949), the German Academy of Sciences in Berlin (1950), the Slovenian Academy of Sciences and Arts in Yugoslavia (1947); and he was made an honorary doctor of the Prague University (1948).

THE FOUNDER OF NONLINEAR OPTICS

Sergei Vavilov's last major work was the monograph entitled *The Microstructure of Light*, which he completed at his country house in Mozzhinka near Zvenigorod in August 1950. The Publishing House of the USSR Academy of Sciences had it printed in the series *Itogi i problemy sovremennoi nauki* (Results and problems of contemporary science) in a record-breaking period of time. It came out in December of that same year, and Vavilov still managed to take delight in its appearance. The five thousand copies of the book were sold out immediately and it soon became a bibliographical rarity. Its next impression came out in the second volume of Sergei Vavilov's collected works in 1952.

In this little book we have the summing up of Vavilov's own scientific activity over a period of thirty years and that of the scientific school that he had created. From a single standpoint we have the treatment of such seemingly disconnected problems as the quantum fluctuations of light, the interference phenomena and the properties of the absorbing medium. *The Microstructure of Light* is a striking example of how profound and purposeful Va-

vilov's research within all those years had been, and how adamant he had been in his quest to discover the nature of light phenomena.

The work on his monograph brought Vavilov great satisfaction. He wrote: 'I have just finished the book *The Microstructure of Light*, in which I brought together and reconsidered quite a few of my own works and those of my colleagues. This is useful for myself and for others: only that which is most important and has stood the test of time is brought out. What I have now before me is a fundamental book, by no means sophisticated and quite readable, in which many former errors have been rectified.'

Vavilov showed that the laws of general optics, which there is some reason to call macroscopic, are by far not always tenable. If one were to start analyzing ultimately small light fluxes and light sources, as well as processes that develop in extremely short periods of time, qualitatively new regularities would begin manifesting themselves. Vavilov gave the new trend in optics reflecting these regularities the name of microoptics.

In the preface to his book he wrote, 'Macrooptics is the optics of considerable light power, long periods of observation and large dimensions of the sources of radiation. What is hidden behind macrooptics is microoptics, which differs from the former in some respects just as the molecular theory of matter is found to be distinct from the thermodynamic theory of it.' The new work did not only sum up the many years of research carried out by Vavilov's scientific school, but also contained a comprehensive programme for the future.

One of the central parts of the monograph concerns the causes of the optical effects that are in a nonlinear way dependent on the intensity of light. In particular, factors responsible for the breakdown of linearity during the absorption of light by a substance are thoroughly investigated. Vavilov came to the conclusion that deviations from linearity are prevalent in nature and belong to a number of basic principles in optics. He introduced the term 'nonlinear optics', which is nowadays widely used.

Vavilov wrote, 'Nonlinearity in the absorbing medium should be observed not only in respect to absorption. The latter is connected with dispersion, for which

reason the velocity of light in the medium should also, generally speaking, depend on the light power. For exactly the same reason, and in the general case, there should exist the light power dependence, i.e. the violation of superposition in other optical properties of the medium, such as double refraction, dichroism, rotary capacity, and so on. It is the astrophysicist who has to continuously deal with "nonlinear optics" of the medium in his theoretical analysis of conditions in the interior of the stars. As a result of the enormous density of light energy in the stars at temperatures measured in many millions of degrees the absorption and velocity of light propagation within the star interior should highly depend on the light power. Nevertheless... the researcher in optics finds nonlinearities and considerable violations of superposition even in the modest conditions of his laboratory, particularly when studying phosphorescent media. However, physics has become so well accustomed to ordinary optics linearity that up to now there does not exist even a formally rigid mathematical system for the solution of concrete "nonlinear" optical problems.'

Sergei Vavilov's research on nonlinear optics was initiated at the time when physics could avail itself of only limited possibilities. Thus the results that were achieved in those far off years seem even more valuable today. Academician Rem Khokhlov wrote, 'It is common knowledge that S. Vavilov is the founder of nonlinear optics. His work in this field had begun long before lasers came into existence. The first nonlinear effect was discovered by S. Vavilov and V. Levshin in 1926 and consisted in the saturation of the absorption of light in uranium glasses. Later S. Vavilov elaborated a vast programme of research into nonlinear optical phenomena. Unfortunately, his life ended before the programme could be accomplished.'

Nearly forty years have passed since Vavilov wrote *The Microstructure of Light*. Time has fully confirmed his remarkable scientific farsightedness. Even in Vavilov's lifetime research on the theory of nonlinear oscillations began to develop intensely, its main concepts were then further treated in the field of optical frequencies.

The rapid progress of nonlinear optics began with the creation of lasers—the new powerful sources of coherent

light radiation. Under its activity nonlinear effects began to emerge in gases, liquids and solids. Lasers have found a wide application both in science and in the national economy. Nonlinear optics has become one of the most promising trends in physics, it has become a field of science where a large number of scientists work together most successfully.

Sergei Vavilov died ten years before lasers were created. However, he had almost achieved an understanding of the possibility of producing sources of coherent radiation. In his monograph he wrote, 'Is the possibility of obtaining coherent light over an adequately long period of time from two different particles of a substance located at a distance measuring several times the diameters of the particles excluded? Presumably, not. If two (or more) particles of this kind are at one and the same time in the excited state for a duration that is considerably greater than the period of light vibrations, then an interaction, or (in quantum terms) exchange forces are bound to emerge ... This results in that the radiation of both particles should become coherent and connected in phase. What is experimentally required here is a high degree of excitation... and a luminescent medium, which gives rise to a molecular "spontaneous" glow of long duration....'

In 1965 the First All-Union Conference o n Nonlinear Optics was convened. Since then conferences of this kind have been held regularly. They always draw a wide circle of scientists, and the number of reports has become so great that hardly any time is left for discussions.

In 1970 at the scientific centre of the Siberian branch of the USSR Academy of Sciences—the academic town near Novosibirsk—the first conference in nonlinear optics was organized. The number of its participants was limited and it was planned as a quorum of the leading scientists in this branch of studies, which was to discuss problems of major current importance. R. Khokhlov suggested that these conferences should be named in honour of Vavilov. The Vavilov conferences have become traditional and are regularly held in the academic town with invariable success.

Vavilov's monograph *The Microstructure of Light* is by right now considered to be classic. In 1952 Vavilov was posthumously, and for the fourth time, awarded

the State Prize of the USSR 'for the outstanding research in the physical sciences and for the scientific works *The Microstructure of Light* and *The Eye and the Sun*'.

'LOOKING BACK ON THE NEEDS OF THE MOTHERLAND...'

A true scientist does not distinguish between fundamental and applied research: both of them are equally important to him. He attaches particular importance to the kind of practical application his elaborations find.

Sergei Vavilov was this kind of scientist. Working on the fundamental problems in physical optics, he never failed to consider his duty as a scientist in promoting the development of his country's national economy. This is what he wrote on the subject: 'The all-round Soviet public movement, directed towards the scientific support of industry on the part of science does not in any way restrict the tremendously important theoretical work of our scientists in all fields of knowledge. The Soviet country needs theoretical work, and it requires it on a scale that has so far been unprecedented. But the Soviet scientist concerned with comprehensive theoretical problems should always look back on his people, on the needs of his own country, on what is demanded of him today, and should avail himself of all accessible means to derive from his theoretical generalizations the conclusions that would be useful for the further progress of our Soviet State.'

These were not mere words for Vavilov. It was his profoundest conviction that had been many a time substantiated by his deeds.

Research connected with the creation of the fundamentally new and highly economical sources of light—the luminescent lamps—was initiated by Vavilov as early as 1927 at the Illumination Engineering Faculty of the Higher Technical School. A little later the research was conducted at different places, and then it became centred at three institutes: the Lebedev Physical Institute of the USSR Academy of Sciences, the All-Union Electrical Engineering Institute in Moscow, and the State Optics Institute in Leningrad. The whole work was carried out under the general supervision of Vavilov.

Sergei Vavilov believed in the great future of this research and decisively eliminated all the impediments that were in its way. M. Konstantinova-Shlezinger told the author that it had been most important to prepare phosphor crystals for the new lamps in conditions that were particularly clean. For this purpose a large room with appropriate facilities was required. For some time this room had been occupied by one of the staff members who most apparently had no propensity for scientific work at all, and so Vavilov decided to dismiss him. When Konstantinova-Shlezinger displayed pity for the man, Vavilov explained that his regret was no less than hers, but that there was no other way to accomplish their work being done, and that the discharged person had better look for a job somewhere else where he could be of more use.

On May 30, 1941, at a general meeting of the USSR Academy of Sciences not long before the beginning of the Great Patriotic War, Vavilov made a report on the luminescent sources of light and demonstrated the first models of luminescent lamps. Substantiating the work that had been done along these lines, Vavilov stated, 'Light is the necessary condition for the functioning of the eye—the most subtle, universal and powerful of sense organs. Night deprives man of this organ and his active life becomes passive. The role of artificial light is to keep up his active and invigorating state of mind. What light does is actually prolong the conscious life of man, and this is exactly where its enormous significance lies. Therefore, it is not surprising that nowadays the problem pertaining to the quantity of light becomes so vitally important in technical and economic terms.'

The models of luminescent lamps were handed over for production to the Moscow plant of electric lamps and the 'Svetotekhnika' (illumination engineering) plant also in Moscow. The outbreak of the war, however, hindered their mass production. Their introduction into the national economy began to take place only in the postwar period.

At first the luminescent lamps were of inferior quality, their colour transmission was poor. Illumined faces appeared cadaverous. The experiments with the lamps of high pressure also did not prove to be successful since it was not infrequent that the lamps exploded. Rumours

spread that luminescent illumination was bad for the eyes. Vavilov took it as a joke and recalled that at the end of the nineteenth century, when electric lighting appeared, mothers regarded it as hazardous for their children's health and continued to use kerosene lamps in their bedrooms.

Z. Morgenshtern recalled that once Vavilov said, 'Imagine our lamps on Kuznetsky bridge. People looking like corpses will be walking all round the place, while the lamps will start exploding with some high official getting injured. Hot water will be what we shall be heading for.' This was certainly a joke, but Vavilov and his colleagues went on working hard to improve the luminescent lamps and their labour was crowned with success.

The usual sources of light—incandescent lamps—are not economical in the least. A large percentage of energy in them (95-96 per cent) is expended on the infrared radiation that the eye cannot see, and only 4-5 percent is spent on the radiation of visible light. In addition, the radiation spectrum of incandescent lamps is markedly shifted to the long waves as compared with the spectrum of daylight. This results in that the illumined objects acquire an irregular shade of colour.

When it is radiating, the incandescent lamp uses the energy of the metallic filament, which reaches a state of incandescence when the electric current is on, and its glow follows the laws of temperature radiation. A drop in heat losses and an improvement in the spectral composition of the radiation of an incandescent lamp can be achieved only by an increase in the temperature of its filament.

But to make the radiation of an incandescent lamp approach that of daylight, it is necessary to raise the temperature up to that of the Sun, which is approximately 6000 °C. This is absolutely impossible since all the materials we have to deal with in nature and of which the filament is produced are characterized by a much lower melting point.

As is known, luminescence is not accompanied by the heating of a body: its nature is quite different from that of thermal radiation. The luminescent lamp represents a glass tube from which the air has been evacuated and replaced by mercury vapours at a pressure of about

0.01 mm Hg. The interior walls of the tube are coated with a thin layer of an inorganic crystalline luminescent substance known as phosphor crystal. Electrodes are introduced into the tube from both of its ends. They have the appearance of small spirals that are connected with the power-supply system by means of special starters.

When the current passes through the electrodes the latter become incandescent and electrons escape from their surface. An electric charge occurs inside the tube in the mercury vapours, as a result of which ultraviolet radiation emerges, which is absorbed by the phosphor crystal. In a state of excitation the phosphor crystal emits visible radiation of the required spectral composition.

The spectral composition itself depends on the properties of the phosphor crystal that is used, which makes it possible to vary it within a fairly large range. Phosphor crystals that emit a glow similar to that of daylight are usually selected, which accounts for the reason that luminescent lamps are often referred to as daylight lamps.

In terms of economy, luminescent sources of light have a fourfold advantage over incandescent lamps. They also have other advantageous properties, which allow them to be used for the illumination of workshops at factories, in mines, art galleries and dwellings. Their production is on the rapid increase, and it will not be long before the incandescent lamp, after being replaced by the luminescent source of light, will be available for inspection only at museums of the history of technology.

The emergence of luminescent lamps has become an actual revolution in illumination engineering. Its benefit to the public has been enormous and the money it helps to save amounts to billions of roubles. It was Vavilov's belief that with the ever growing use of luminescent sources of light the word 'luminescence' itself, just as the words 'radio' and 'electricity', will lose its purely technical denotation and become a common word used in everyday speech.

Vavilov insisted that explosion-proof luminescent lamps should be placed in the mines of Donbass, and widely installed in the stations of the Moscow Metro, in the multi-storeyed buildings of the capital and for the illumination of the Hermitage in Leningrad. The creation of new sources of light received a very high token of

appreciation. In 1951 the group of scientists that included Sergei Vavilov, Vadim Levshin, Valentin Fabrikant, Maria Konstantinova, Fatima Butaeva and Viktor Dolgopolov was awarded the USSR State Prize for the development of luminescent lamps.

Vavilov also made a great contribution to the development of methods for luminescence analysis. His fundamental research into molecular luminescence formed the theoretical basis for its new application. When it was shown that each luminescent substance had a characteristic radiation spectrum, Vavilov suggested that this property should be employed for analytical purposes. Taking into consideration the spectral composition of the radiation of a sample and the intensity of its glow, it is possible to conduct not only qualitative, but also quantitative luminescent analysis. The elaboration of methods for quantitative luminescence analysis had for the first time been initiated before the war by M. Konstantinova-Shlezinger, whom in 1943 Vavilov invited to work at the Lebedev Physical Institute of the USSR Academy of Sciences.

It occurred that luminescence analysis was characterized by a number of qualities that were advantageously distinct from other types of analysis. In the first place it was markedly sensitive. By employing luminescence methods it becomes possible to detect one hundred billionths of a gram of some substance in one cubic centimetre of a sample. Another important advantage is that the substance under investigation is preserved whereas in other types of analysis the sample is destroyed completely. This fact proves to be highly significant when dealing with insufficient quantities of rare substances that are difficult to extract.

Today luminescent analysis is widely used in scientific research and in various branches of the national economy. Vavilov's efforts to provide the facilities required for research on luminescent analysis can hardly be overestimated. He also deemed it necessary to popularize the achievements of luminescent analysis by organizing special conferences and by seeing to it that guides and manuals on this subject were published.

Vavilov asked M. Konstantinova-Shlezinger to write a monograph on luminescent analysis at a time when she had practically no experience as a writer of scientific

prose. He gave her advice and provided her with a very proficient editor. In 1948 the monograph was published and was of great assistance to those engaged in research.

On Vavilov's initiative the monograph by P. Pringsheim and M. Fogel on the luminescence of liquids and solids and its practical application was translated from the English. In it considerable attention was paid to luminescent analysis. As was suggested by Vavilov, Konstantinova-Shlezinger began to work on the compilation of papers on luminescent analysis. The first volume of this collection came out in 1951 already after the death of Sergei Vavilov. It was edited by V. Levhsin.

Some of the research on luminescent analysis was accomplished with the immediate participation of Vavilov himself. Thus, in his laboratory at the State Optics Institute the express method of sorting various types of optical glass by means of luminescent analysis was elaborated and instituted into practice. When Vavilov was Chairman of the Commission on studies of the stratosphere, he initiated research at the Lebedev Physical Institute of the USSR Academy of Sciences which was aimed at determining the content of ozone in the upper layers of the atmosphere by a luminescence method. These investigations were essential to geophysicists and for the solution of a number of theoretical and practical problems. The method was worked out by M. Konstantinova-Shlezinger.

In his attempt to introduce the methods of luminescent analysis into industry, Vavilov regularly commissioned Konstantinova-Shlezinger and her group of researchers to supervise the training in luminescent analysis of industrial workers. He initiated research on elaborating luminescence methods for the flaw detection of metals.

Vavilov also made a significant contribution to the organization of research on ultraviolet and luminescence microscopy, which found its application in biology, medicine, geology and some other industrial processes. Under his immediate guidance, this research was initiated at the State Optics Institute by E. Brumberg before the very outbreak of the war. In 1942 E. Brumberg reported the first results to the physics and mathematics section of the USSR Academy of Sciences. In a later period they developed original methods and designed optical instru-

ments for the study of diverse objects in ultraviolet rays.

Enormous significance was acquired by the research conducted on the properties and the creation of new types of phosphor crystals, which have been frequently mentioned. These phosphor crystals are now widely used in the screens of cathode-ray devices (oscillographs, kinescopes, electron microscopes), medical X-ray screens, as well as in luminescent lamps. Vavilov, sparing no effort in encouraging their creation, was at the same time rather sceptical about phosphor crystals as objects of scientific research. He considered them to be dirty and jokingly said that 'one might as well analyze processes in a buckweat gruel'. As far as the development of the theory of their glow was concerned, he ironically compared such attempts with 'the development of a theory of a cobbled road'. Apparently, this was exactly the reason why in his own research he had remained invariably true to luminescent solutions.

On Vavilov's initiative, studies on phoshor crystals were for the first time initiated in the Soviet Union at the Physics Institute of Moscow State University by Vadim Levshin and his postgraduate student Vsevolod Antonov-Romanovsky as far back as 1932. Levshin wrote that it was Vavilov who had stimulated the development of research on the phosphorescence of phosphor crystals.

As was already mentioned, in the years of the Great Patriotic War, Vavilov did an enormous amount of work on the utilization of luminous compounds in cases of blackout and in the solution of other problems. It was his own idea that phosphors should be used for the detection of infrared radiation. This idea was realized at the Lebedev Physical Institute of the USSR Academy of Sciences under the guidance of Levshin. The impact of infrared radiation on the optical properties of phosphor crystals was investigated.

At the end of the forties, phosphors that emitted an intense light flash under the activity of infrared rays were obtained. The development of flash phosphors was of great scientific and practical value. For this research, the group of scientists headed by V. Levshin was awarded the Academician L. Mandelshtam Prize of the USSR Academy of Sciences in 1947 and the USSR State Prize in 1952.

As the head of the State Optics Institute Vavilov di-

rected and coordinated all the basic research in the field of theoretical and practical optics. He took part in the elaboration of diverse problems, ranging from the choice of welding techniques and the control of the quality of optical glass to the creation of the most up-to-date optical equipment. For instance, he himself participated in the elaboration of methods for calculating and assessing aberrations of wide-angle wide-aperture photographic systems. As early as 1936, he initiated at the State Optics Institute studies on dichroic media (uniaxial crystals characterized by birefringence that acquire various shades of colour in transmitted light when the directions of observation are mutually perpendicular). Polarizing filters were also developed. They too have found wide application in various optical instruments and physical methods of research.

The publication of handbooks for those engaged in research was accomplished owing to Vavilov's great efforts. Thus, under his editorship, *A Handbook of Military Optics* was issued, which was followed by the publication of the work *Optics and Military Practice*. The books were intended for the commanding personnel of the Soviet Army and for teachers and students of military academies and schools. No less substantial was the two-volume work *A Handbook of Illuminating Engineering*.

Vavilov's cooperation with Mashgiz Publishers calls for more than a brief mention. For many years he had been chairman of the scientific council concerned with problems in the construction of instruments and a member of the editorial board of the periodical *Priborostroenie* (instrument engineering). However, this was not his major activity.

Between 1943 and 1948 Mashgiz was headed by Yulia Konyushaya. She told the author of this books that right after the war, when the national economy of the country was being built up again, Soviet engineers were in need of the latest reference books and handbooks. In 1947 measures were taken to publish the sixteen-volume encyclopaedic reference book *Mashinostroenie* (instrument engineering) as speedily as was possible. It had to provide general information on the most advanced scientific and technical achievements concerning the theory, design and manufacturing engineering, instruments, automation means, etc.

Yevgeni Chudakov was appointed chief editor of the book. It was scheduled to be published within an incredibly short period of time. There was only one month allotted for each volume to be written and published. Those involved in this work included more than five hundred scientists and innovators in industry.

Vavilov was busy with the project every day. He reviewed the proofs of the prospect and plan of the edition, always gave his advice and telephoned the authors of the entries himself. Not infrequently he rang up the establishment where these authors worked and spoke of the necessity to consider their participation in the writing of the reference book as an urgent task of primary importance.

The publication of the volumes followed a regular schedule and what was even more surprising was that they appeared prior to the dealings. Each volume was issued in twenty-eight, instead of thirty, days. The work was issued between 1947 and 1948 and provided enormous assistance to engineers and technicians.

THE HISTORY OF SCIENCE IS REQUIRED BY ALL

Anyone who came in contact with Vavilov was surprised at the wide scope of his cultural interests. Vavilov used to say, 'A researcher ought to know the history of his science'. Academician I. Frank wrote that he could not remember a single question on the history of physics that Vavilov could not immediately and most exhaustively answer, while Academician I. Bardin said that Vavilov's attachment to the history of science was as great as his love for science itself.

The year 1980 saw the first issues of the periodical *Problems in the History of the Natural Sciences and Technology.* It was not by chance that its first number opened with the words of Sergei Vavilov, 'The history of science is required by all of us, just as is science itself. We need it so that we could act, know nature and make it serve our own purposes. We are convinced that science together with its history forms an essential link in the development of Socialist society.'

When still a young man Vavilov had begun collecting books on the history of natural science. As the years went

by, his interest in this particular history grew. N. Tolstoi wrote that one of Vavilov's remarkable qualities was his ability to associate the history of science with the scope of contemporary ideas. He held the scientists of the bygone days in high esteem, and had a special gift for proving that much of what seems a discovery nowadays is no more than what existed before and was obliterated with the passage of time. For instance, an experimental method that is considered to be new actually turns out to have been the favourite one of some old Master, whose name is not forgotten today, though his deeds have fallen into abeyance.

Vavilov, more than anybody else, could appreciate the significance of the history of science for scientific research. Working at the USSR Academy of Sciences, he used his influence and spared no effort to organize studies in the field of the history of science. As far back as 1934 Sergei Vavilov became head of the physics-and-mathematics section and a member of the scientific council of the Institute of the History of Science and Technology of the USSR Academy of Sciences. In 1938 he was appointed Chairman of the History Commission of the USSR Academy of Sciences, and since 1944, when the Institute of the History of Natural Sciences and Technology was founded, he worked there as a member of the scientific council and also of the editorial board of the published works of the Institute and the series called 'Scientific Heritage'.

In 1945 Vavilov headed the academic commission on the history of physical and mathematical sciences upon the death of A. Krylov. On his initiative the training of specialists in the history of physical and mathematical sciences was discussed at a meeting held by the commission. Laying particular stress on how important the training of specialists in the history of science was, Vavilov pointed out that a qualified approach to the problems in history could be undertaken only by those with a broad outlook who had also contributed to science themselves. In his opinion the history of science should by no means serve as a haven for those incapable of doing scientific research on their own. The commission adopted a resolution that only doctoral candidates could apply to study in the field of the history of physics and mathematics.

Anyone who entered Vavilov's office at the Lebedev

Physical Institute of the USSR Academy of Sciences for the first time could not but immediately notice the huge old closet in which its owner had very carefully placed the first specimens of galvanoplastics invented by Boris Yakobi, the miniature instruments made by Pyotr Lebedev himself to determine light pressure, and many other relics. This little museum could in no better way reflect the profound interest of the director in the history of his country's physical science.

Among Sergei Vavilov's works in the field of the history of science a central place is occupied by research on the life and activity of Isaac Newton, whose works Vavilov had studied for over twenty years. This research was basically devoted to the optical studies of the great English physicist. Vavilov's research had something in common with what A. Krylov wrote on Newton's works in the field of mathematics, mechanics and astronomy. In their country's science, A. Krylov and S. Vavilov had founded a new trend, which may now be well referred to as Newtoniana.

Vavilov had been interested in Newton's works ever since he was a student. In 1927, when the bicentenary of Newton's death was commemorated, Vavilov published his first work on Newton in the journal *Uspekhi fizicheskikh nauk* (Achievements in the Physical Sciences). In the same year he also translated Newton's famous *Optics* into the Russian. He approached this work with the greatest feeling of responsibility.

He wrote, 'My translation was based on the Third English Edition of 1721, the last one that was examined by Newton himself. In some confusing places the translation was collated with the Latin, French, and German versions. I tried to accurately render the text of the original, avoiding as much as possible a word-for-word translation. As far as its style is concerned, the book is difficult for the modern reader, which was hard to overcome without making deletions and attempting to bring it up to date.' Vavilov furnished his translation with comprehensive annotations, which make the reading of this great treatise more accessible.

Conscientious as he was while doing the translation, Vavilov was not fully satisfied with the outcome. In the epilogue he wrote, 'The book is published to commemorate the bicentenary of Newton's death (March 20, 1727

according to the Julian calendar). The printing was somewhat delayed and I managed to do only two proofreadings, which accounts for some of the inadequacies, errors and misprints that one may find in the book. Unfortunately, even now we have to repeat what Newton wrote to Kotz on October 11, 1709 about the impossibility of printing books without misprints.' This kind of exacting attitude toward himself knew no compromise.

Vavilov's translation of Newton's *Optics* came out in the series 'The classics of natural sciences'. Vavilov supplemented the book with a brief biographical note on the life of Newton, which ended with the words, 'It would be superfluous and out of place to speak of the significance of Newton's scientific heritage. No one before or after Newton has ever been able to achieve more in the natural sciences'.

In 1954, after Vavilov's death, the second edition of his translation of Newton's *Optics* was undertaken. Academician G. Landsberg worked on this project. In his preface to the second edition he wrote that acquaintance with the classics of science directly and not through the interpretation of them given in textbooks, was of great importance for the formation of the scientific world view of the young scientist. He went on to explain that this principle had always been ardently supported by Sergei Vavilov, whose influence on the publication of vast classical literature in the Soviet Union was undoubtedly felt. In spite of the fact that nearly thirty years had passed between the first and the second edition Landsberg found it unnecessary to introduce any substantial connections in Vavilov's commentaries.

Vavilov's most significant work on Newton was accomplished when the Great Patriotic War was at its height. In connection with the tercentenary of Newton's birth, which fell in the year 1943, Vavilov wrote his complete scientific biography. It was the time of the Battle of Stalingrad, and in the preface to his monograph, Vavilov wrote: 'In these decisive days of hardship when the question is whether our Motherland will survive or not one cannot possibly remain heedless of the banner of culture under which and for whose honour our people are engaged in a deadly struggle against the Attilas and Genghis Khans of today.'

Vavilov was enraptured by Newton's genius. He **kept**

in his memory the Latin inscription by Lucretius on the monument that had been erected to Newton at Trinity College in Cambridge in 1755 which declared that with his intellect the great scientist had surpassed the human race. Vavilov shared this appreciation.

In his book *Isaac Newton*, Sergei Vavilov made every effort to give as accurate an account as possible of Newton's thoughts and ideas and an interpretation of their significance for modern science. He pointed out that Newton's life and creative activity would be interesting and instructive for the coming generations. In 1945 the second edition of Newton's biography written by Vavilov appeared. Later it was included in the third volume of S. Vavilov's works. The book about Newton was reissued seven times in countries outside the USSR. It was translated into Roumanian, Hungarian and German.

Another work of no minor importance was Vavilov's translation into Russian of the famous and yet thoroughly forgotten, *Lectures on Optics* by Newton which were delivered by the English scientist between the years 1669 and 1671. Vavilov provided his translation with most interesting commentaries. He had begun this work long before the war, but managed to complete it only in 1944 and have it published two years later.

As was customary with him, Vavilov approached this work with creativity and awareness of what a responsibility it was. In the epilogue he wrote: 'The translation of Newton's Latin is a difficult task, and I must have made quite a few mistakes. I think that when it comes to the translation of the classics of science, precision should be compatible with an adequate degree of clarity for the modern reader, and what I tried to do was to find the middle course between the unreadable interlinear translation and its more intelligible and explanatory version'. Vavilov's achievement made this remarkable work of Newton accessible to many a reader. He wrote: '*Lectures* lend themselves to be discovered anew, and, moreover, they reveal much that is novel and interesting even for the contemporary reader. Their pages bear most evident traces of Newton's great experimental and theoretical genius and at the same time one cannot but feel their author's youth, his straightforwardness and decisiveness.'

It would be of some interest to mention that even in Newton's own country the publication and complete

translation of this work into English from the Latin were not carried out. In Vavilov's opinion this had done no little harm to the development of optical science. He wrote: 'If *Lectures* had been opportunely published... and had not remained a poorly assimilated material in the heads of Cambridge students and a practically unknown manuscript in the University archives, their role in the study of light would have been exceptional. In this treatise, for the first time in the history of science, optics in its integrity and not merely the geometrical optics of Euclid and Ptolemy, undoubtedly became a physics and mathematics subject.'

Vavilov worked on the monograph on Newton and on the translation of his *Lectures on Optics* in the days of the evacuation, when he was deprived of access to any additional literary sources and materials from the archives. One cannot but wonder at the erudition of a person who accomplished the work on so high a level and under such highly unfavourable circumstances.

In the homeland of the great scientist, Vavilov's research into Newton's works was followed with considerable interest and respect. In 1946 Sergei Vavilov was asked to come to England to take part in the celebrations devoted to the tricentenary of Newton's birth, which at their proper time had to be postponed because of the war.

When Vavilov received the invitation, he sent *Lectures on Optics* and the other works by Newton that he had translated into Russian as a gift to the London Royal Society. He could not go to England himself, but wrote a circumstantial report entitled 'Newton's Atomism', which was delivered at the grand meeting of the London Royal Society by Professor Henry Hallett Dale, an honorary member of the USSR Academy of Sciences. The report was a great success and was published in both Russian and English.

Sergei Vavilov considered it to be his primary duty to popularize the works of the great Russian scientist Mikhail Vasilyevich Lomonosov. He was convinced that the study of Lomonosov's works would promote a general uplift of culture and science in his own country. Speaking of the significance of Lomonosov Vavilov wrote, 'This peasant from the shores of the White Sea whose intellect, willpower and physical strength overcame the innumerable obstacles presented by the regime, way of life, tra-

ditions and prejudices of old Russia, and who got down to the very bottom of science and became one of its outstanding men himself, on a level with Lavoisier and Bernoulli, served himself as an example of the enormous latent cultural possibilities of his great nation.'

Some time later Vavilov pointed out: 'Mikhail Vasilievich Lomonosov is not merely one of the remarkable representatives of Russian culture. Even in his lifetime, his personality radiated a very special kind of light for his Russian contemporaries which signified that their ambitions to see the power of a national genius had been fulfilled. His deeds for the first time and most decisively refuted the opinion of the foreigners who happened to be in Russia at that time as well as the Russian sceptics themselves that the Russians are reluctant and even incapable of doing any scientific work on their own. Lomonosov became a living incarnation of Russian culture with all its diverse and specific features, and what was presumably most important was that an ordinary peasant from one of the remotest villages of Arkhangelsk province had forever done away with the bias that science and the arts, if such did exist in Russia, were to be found only among its elite... If we tried to look back, we would undoubtedly see that the cornerstones of our science were laid in the past by Lomonosov himself.'

Vavilov considered the research into Lomonosov's works to be a task with which an individual or even several scientists could not possibly cope. When in 1938 he became Chairman of the History Commission of the USSR Academy of Sciences, he involved a wide circle of researchers in this task. He put forward before the commission the problem of resuscitating 'the gigantic personality of the first great Russian scientist'. In his opinion it was a most urgent task, and it was with bitterness that he spoke of the enormous harm that had been done to Russian science in its time when under the czarist regime there were few who were anxious to have Lomonosov's heritage serve their country's progress.

And again it was with regret that Vavilov said, 'All that Lomonosov had achieved in the field of physics and chemistry was buried in books that remained unread, in unpublished manuscripts, in the deserted and scattered laboratories on Vasilyevsky Island and along the Moika river... the numerous ingenious instruments invented by

Lomonosov were not only not produced, but also no effort was made to preserve them.'

Vavilov thought of publishing a collection of papers under title *Lomonosov* which was to be devoted to the creative activity of the great scientist. These papers were meant to bring together the efforts of all the Soviet specialists on Lomonosov.

The one hundred and seventy-fifth anniversary of Lomonosov's death fell in the year 1940. On Vavilov's initiative the History Commission of the USSR Academy of Sciences issued the first volume of such papers, which opened with a preface that was written by Vavilov himself. The volume contained not only several wonderful articles that gave a profound insight into Lomonosov's works, but also included some of the scientist's unpublished papers.

The second volume of this collection of papers came out in 1946, and in 1951, three months after Sergei Vavilov died, the third volume appeared, which just as the first two, had been compiled and edited by Vavilov himself.

In 1940 Vavilov came up with the suggestion that annual conferences devoted to the memory of Lomonosov should be organized in Leningrad on the day of the scientist's birth (November 19) and on the day of his death (April 15). The war delayed the implementation of this idea, though since 1944, such conferences were regularly held under Vavilov's direction, who drew the most prominent historians of science to participate in them.

In Vavilov's lifetime, twelve Lomonosov conferences took place at which thirty-five analyses of Lomonosov's creative activity were summed up. At first the conferences were held in different buildings of the Academy, but since 1949, when the M. V. Lomonosov Museum was opened in Leningrad, the circular hall of the Academy's former Chamber of Curiosities has been their permanent address.

After one of such reports on Lomonosov's mirror telescopes Vavilov suggested that the scientists should not restrict themselves entirely to the study of archival materials, but should try to find and collect the Russian optical instruments, and other scientific apparatuses dating back to the eighteenth century. Within a period of time it became possible to create a unique collection of

optical instruments that had been manufactured in Russia in the days of Lomonosov.

It was again Vavilov's idea to organize the 'Lomonosov Readings' for the young people in Moscow, who were given the opportunity to hear leading Soviet scientists speak on the history of their country's science. The first of such readings took place in March 1945 in the Grand Hall of the Polytechnical Museum and was opened with S. Vavilov's report 'Lomonosov and Russian Science', which is by right considered to be one of the best popular science works on Lomonosov. The texts of these lectures were published in large editions and became highly favoured by the public at large.

In 1946 Vavilov proposed that a new academic edition of Lomonosov's works should be prepared. Prior to then Lomonosov's treatises had been published nine times, though all the editions were incomplete. Moreover, some of the works of this scientist had not been translated from Latin into Russian which made them inaccessible to the majority of readers. Lomonosov's letters had also been only partially published. The new collection of his works in ten volumes, with Vavilov as the editor in chief, was meant to fill those gaps. It was decided to reproduce Lomonosov's works written in Latin in both the original and the Russian versions.

By 1957 the edition had been completed. Vavilov was able to edit only the first two volumes before he died. Acknowledging his exceptional role in the publication of Lomonosov's Collected Works, the editorial and publishing board of the USSR Academy of Sciences decreed that Sergei Vavilov's name was to remain on the list of members of the chief editorial board throughout the whole publication of the edition, in spite of the fact that the greater number of volumes came out already after his death.

One of Vavilov's illustrious merits was the organization of the Lomonosov Museum previously mentioned. On his advice it was decided to open this museum at the Institute of Ethnography of the USSR Academy of Sciences in the old building of the Kunstkamera (Chamber of Curiosities), where as early as 1714 Peter I had founded the first Russian Museum—a collection of antiques, various marvels and coins. The building of the Chamber of Curiosities had for a long time served Lomonosov as a place

where he carried on his work. In the middle of the eighteenth century it was badly damaged by a fire and had not been restored. On Vavilov's initiative, the Presidium of the USSR Academy of Sciences adopted a resolution to reconstruct the building of the Chamber of Curiosities to its original form.

The establishments of the Academy, the Hermitage, the Historical Museum and others donated their most valuable exhibits to the exposition. Vavilov, who was an ardent bibliophile and collector, did not grudge parting with many of his possessions. His gift to the Museum included more than thirty rare books from his own library, among which there was Smotritsky's Grammar—the book that had served Lomonosov as a teaching guide to reading and writing in his childhood. The essays of Lomonosov's teacher Christian Wolf written in Latin, and the German translation of Lomonosov's Russian Grammar published in St. Petersburg in 1764 were also donated. The most precious gift, however, was the two-volume novel *Mikhail Vasilyevich Lomonosov* by Ksenofont Polevoy. At one time the book had belonged to Vissarion Belinsky and thus contained the great Russian critic's copious marginalia.

The Lomonosov Museum was opened in January 1949. The event was planned to coincide with the general meeting of the Academy of Sciences devoted to the history of Russian science. The grand conference of the Academy was held in the circular hall of the Chamber of Curiosities. The huge round table at which the Petrovskaya Academy had held its conferences in the past was now surrounded by the leading Soviet academicians with a quill pen placed before each of them.

Sergei Vavilov began the introductory speech stating, 'By opening the Museum of Mikhail Vasilyevich Lomonosov in this building, the walls of which bear the sacred memory for us of the place where Lomonosov himself worked, the Academy of Sciences fulfils its belated duty to the memory of one of the most remarkable people of our past'. In his speech Vavilov set specific tasks before the museum. He said, 'The Lomonosov Museum that is being opened today should serve the purpose of propagating knowledge about Lomonosov and his science among the public at large. At the same time the museum should be the new centre for the further and more profound study

of Lomonosov, and where various objects and documents connected with his name should be assembled.'

Sergei Vavilov's own contribution to studies about Lomonosov were substantial. In 1936 he gave the report 'M. V. Lomonosov's views and works on optics' at a joint session of the USSR Academy of Sciences and Moscow University in connection with the 225th anniversary of the great scientist's birth. This was followed by a series of excellent articles on Lomonosov written at different times. One that should be particularly noted is the research article 'M. V. Lomonosov's night telescope', which was published in the second volume of the collection of papers entitled *Lomonosov*. In it Vavilov for the first time gave a full description of the night telescope invented by Lomonosov in 1756 and outlined the principles of its functioning. The information for this article had been obtained from archival materials that concerned the prolonged discussion over many years about this invention at the St. Petersburg Academy of Sciences and from the notes made by the scientist himself.

Of great importance was Vavilov's initiative to reprint the scientific biography of Lomonosov entitled *An Account of Mikhail Vasilyevich Lomonosov's Life and Activity*, which was written in 1911 by the chemist and historian of science Boris Menshutkin, who was the first to show the outstanding significance of Lomonosov's works for the further progress of chemical science. Those works were one hundred, or even one hundred and fifty years ahead of their time. Menshutkin's treatise was reissued in 1947 and contained some new material. The book now contained a chapter contributed by Vavilov and devoted to the optical studies of Lomonosov. He also took part in the thorough revision of the chapter dealing with the contributions of the scientist in the field of gravitation.

In his works Vavilov had always tried to emphasize the continuity of ideas in the course of their development. This made his historical research particularly valuable. This concept found its most coherent expression in his work on the history of physics at the Academy of Sciences, entitled *The Physics Study, the Physics Laboratory, and the Physics Institute of the USSR Academy of Sciences over a period of 220 years (1725-1945)*.

One should never forget the names of the scientists who laid the foundations of modern science, Sergei Ivanovich

used to say. He liked to repeat the words, 'Anniversaries come and go, but books shall remain forever'. During the war he proposed publishing special collections of papers devoted to the tricentenary of the death of Galileo and the birth of Newton. Immediately after the war, on Vavilov's initiative, the Academy of Sciences had a grand celebration of the three-hundred-year anniversary of the birth of René Descartes. In connection with the two-thousand-year anniversary of the death of the greatest ancient materialist philosopher Titus Lucretius Carus which fell in the year 1945, it was owing to Sergei Vavilov that the great man's immortal epic *De rerum natura* (Concerning the Nature of Things) had been translated and published. After thoroughly acquainting himself with the works of Lucretius, Vavilov gave the report 'The Physics of Lucretius' at a joint session of the Departments of Physics and Mathematics, History, Philosophy, and Literature of the USSR Academy of Sciences in 1946.

Vavilov produced a great many articles and essays on the life and activity of famous scientists. In addition to those mentioned above, of significant interest are his works on Christian Huygens, Michael Faraday, Albert Abraham Michelson, Leonhard Euler, Pyotr Nikolayevich Lebedev, Vasili Vladimirovich Petrov, Pyotr Petrovich Lazarev, and Paul Langevin. The scientific activity and the personality of each scientist were presented in a new aspect hitherto untreated. Of particular interest to Vavilov were the works of Academician V. Petrov at the beginning of the nineteenth century. Vavilov established that Petrov had been the first to study the phenomena of luminescence.

Vavilov had always worshipped the poetic genius of Aleksandr Pushkin. In his own words, 'The works of Pushkin are a multilateral reflection of the best qualities of the Russian people: their unaffectedness, straightforwardness, generosity, devotion to their country, love for people as individuals, unrestrained love for freedom, subtle intellect, and sense of beauty.' Vavilov directed the celebrations that were held in 1949 in commemoration of the sesquicentenary of Pushkin's birth. He did much work to perpetuate the memory of the great poet. In those days of the jubilee his excited voice resounded in the Hall of Columns of the House of Unions, in the assembly hall of the Lyceum, and in the museum in the former home of the poet in the village of Mikhailovskoye.

Neither did Vavilov remain heedless of the bicentenary of the birth of the Russian revolutionary and writer Aleksandr Radishchev, whom Vavilov called the revolutionary '*chevalier sans peur et sans reproche*'. In 1949, with Vavilov as Chairman, a general meeting of the USSR Academy of Sciences in honour of this date was held.

In 1949 the centenary of birth of the great Russian physiologist Ivan Pavlov was marked. When speaking at the opening of the I. Pavlov museum in Leningrad, Vavilov Stated, 'The Soviet country is proud of its great son and cherishes the memory of him not only as a remarkable scientist, but also as someone who was Russian in every respect, and who loved his Motherland, his people, his culture, and his own Russian art with all his heart.'

In his speeches devoted to the life and work of Academicians Aleksandr Baikov, Aleksei Bakh, Aleksandr Karpinsky, Vladimir Komarov, Aleksei Krylov, Vladimir Obruchev, Nikolai Papaleksi, Vavilov emphasized the most prominent contribution that each of them made to world science.

Looking through the back issues of newspapers and magazines one cannot stop wondering where Vavilov could find the strength and time for all his activities, since not a single event in the cultural life of the country seems to have escaped his notice. He spoke on the days when plaques were fixed to the walls in memory of the outstanding Russian scientists Vasili Petrov, Mikhail Ostrogradsky, Boris Yakobi, Yakov Grot, Pafnuti Chebyshev, Nikolai Marr, Frants Levinson-Lessing, Aleksandr Karpinsky, Vladimir Vernadsky, and Ivan Pavlov (the USSR Academy of Sciences building in Leningrad). Vavilov also gave a long speech on the occasion of the eight-hundred-year anniversary of Moscow.

The last public speech Sergei Vavilov gave was on December 11, 1950 at a grand joint meeting of the USSR Academy of Sciences, the USSR Union of Soviet Writers, and the Arts Committee of the USSR Council of Ministers in connection with the sesquicentenary of the first edition of *The Lay of the Host of Igor*. The concluding words of his peroration were 'Glory be to the Russian patriot, the great author of *The Lay of the Host of Igor*! Glory be to our people.'

Vavilov was deeply interested in the philosophical problems of the natural sciences. His research into phys-

ics and philosophy were not isolated but presented an integral whole. He wrote, 'Those of the natural scientists who are averse to philosophy assume that conscious scientific study is possible without any philosophical premises. However, even a cursory analysis of a particular scientific research work is bound to reveal the philosophical background (conscious or existing beyond the author's competence) against which the research has been accomplished and the conclusions were drawn. What is of primary importance here is that the philosophical premises are by far not wholy irrelevant to both the results and the further progress of the work: they can serve either to impede or stimulate the development of science'.

With the most prominent scientists, and Einstein, in particular, serving as an example, Vavilov showed the negative impact of an idealistic world outlook upon creative activity. In his article 'V.I. Lenin and Physics' he wrote, 'The practical fatality in the latest stages of the development of the theory of relativity finds its expression in the experimental proof of the erroneousness of this speculative and idealistic trend. The fallacious method has deteriorating consequences, and in the case of mechanism as well as idealism it invariably leads to stagnation in science'.

Having arrived at the concluston that 'what forms the basis of progressive natural science, and advanced physics in particular, cannot be any other philosophy but dialectical materialism,' Vavilov considered it his duty to spare no effort in propagating Marxist-Leninist theory. He persistently called upon scientists 'to learn to walk' along the road of dialectical materialism.

Vavilov wrote a number of papers that were a substantial contribution to the Marxist-Leninist philosophical literature. The most prominent of them are: *Dialectics of Light Phenomena* (1934), the already mentioned *V. I. Lenin and Physics* (1934), *New Physics and Dialectical Materialism* (1939), *The Development of the Idea of Matter* (1941), *Lenin and Contemporary Physics* (1944), and *Lenin and the Philosophical Problems of Modern Physics* (1950).

These particular works, which were the result of Vavilov's meditations over a period of many years, proved to be so profound and interesting that they could not but draw everybody's attention as soon as they appeared.

A. Sevchenko told the author of the present book about his discussion with Vavilov shortly after the war had ended. It was the time when Sevchenko was the party organizer of the laboratory of which Vavilov was in charge at the State Optics Institute. On one occasion it so happened that Sevchenko found himself in the company of Vavilov with no one else present. Sevchenko, with his tongue in his cheek, told Vavilov it was to no avail that he wrote so much on philosophical subjects since it was very easy to go wrong somewhere, and he wondered if he, as the party organizer, would not be compelled to speak about this to his teacher.

Vavilov smiled and said that he was protected from this kind of situation because 'Iosif Vissarionovich Stalin and he had an agreement that each of his manuscripts would be sent to him for examination, and if no criticisms arose within a period of ten days, the article received his full permission to be published. So far there has been no critique of any kind'.

Vavilov attached great importance to Lenin's book *Materialism and Empiriocriticism*, which, as far back as 1909, when he was still a young man, he had thoroughly studied. Many years later he wrote, 'Had Lenin's book been opportunely read by physicists, it would have relieved science of many imaginary "crises" that came its way in the course of its development'. Vavilov laid particular stress on the fact that this book had become the desk-book of every Soviet intellectual, the book that served the country as a textbook in dialectical materialism, and had become the philosophical guide for every Soviet scientist.

Vavilov considered that 'for the new physics the method of dialectical materialism had become a necessity, and it was the method which he most widely employed himself.' In analysing the latest achievements in physics, he demonstrated the irrefutableness of the Lenin's thesis concerning the infinite character of matter and its forms. Discussing the progress that had been made in the physics of crystals, he mentioned in his writings of the fulfilment of one of the basic laws of dialectics, viz. the law of the transformation of quantity into quality. In Vavilov's work much is said of energy and mass, their interaction, and the laws of the conservation of matter and motion. Vavilov rejected the interpretation furnished by some

sicentists that mass and energy are interrelated through the transformation of the former into the latter and vice versa.

Vavilov's works on the elucidation of the nature of light are of no minor philosophical importance either. His conclusion concerning the unity of wave and corpuscular properties of light is a convincing physical argument in favour of one of the fundamental laws of dialectical materialism—the law of the unity and conflict of opposites.

Vavilov was indefatigable when it came to supporting the dialectical approach to the latest achievements in physics. The non-Party scientist rendered enormous assistance to the Party in its ideological upbringing of the people. Recalling this, P. Feofilov wrote that Vavilov was the organizer and a participant of a number of discussions about the philosophical problems of physics. He spoke in defence of some of the most prominent Soviet physicists who were accused by some of the philosophers of adhering to 'physical idealism'. Mention should also be made that Vavilov himself did not remain immune to charges of this kind.

On Vavilov's initiative a section on the philosophy of natural sciences was organized at the Institute of Philosophy of the USSR Academy of Sciences. The first head of this department was Sergei Vavilov himself.

SCIENTIFIC KNOWLEDGE FOR THE PEOPLE

The liveliest interest in the most diverse fields of human culture and the ability to bring home to his listeners the most complicated scientific problems in a form that was both vivid and accessible had by right won Sergei Vavilov the reputation of a classic popularizer of scientific knowledge. The problem of science versus the arts did not exist for him as such. He regarded science, literature, and art as inseparably connected with each other.

He greatly loved books and reading, and it was probably this that explained his indefatigable activity as editor and publisher, which is by far not typical of scientists in general. One of his great merits was his revival at the Academy of Sciences of the Lomonosov tradition whereby

popular science books were written by scientists with the aim of enriching the general public's knowlegde.

In 1932 a resolution was adopted to institute work of science popularization; while in the following year the Presidium of the USSR Academy of Sciences organized a commission responsible for the publication of popular science literature with Vavilov in charge. Vavilov worked in this commission for eighteen years until the very end of his life.

The commission started functioning by creating a popular science series of books to be published at the USSR Academy of Sciences. In 1938, on Vavilov's initiative, this series was divided into three groups, with each of them aimed at a different reader. The first subsection was intended for the reader who had an adequate scientific background, the second was meant for the workers, and the third was to serve the interests of those working in agriculture.

In 1933 Vavilov became a member of the editorial board of the periodical *Doklady Akademii Nauk SSSR* (Reports of the USSR Academy of Sciences) (and since 1945 he had been its editor-in-chief). In 1939 Vavilov was appointed managing editor of the *Zhurnal Eksperimentalnoy i Teoreticheskoy Fiziki* (Journal of Experimental and Theoretical Physics), in which capacity he had remained till the end of his life. Moreover, between 1939 and 1941 he was the editor of *Fizicheski Zhurnal SSSR* (USSR Physics Journal), which was published in English, and from 1945 to 1951 he was a member of the editorial board of the periodical *Vestnik Akademii Nauk SSSR* (News-bulletin of the USSR Academy of Sciences).

Vavilov devoted much time to his editorial activity. Academician B. Vul told the author of this book that before the war Vavilov and he lived in the same house in Spiridonovka (now known as Aleksei Tolstoy Street) and that very often they used to return home from the Institute at about eight or nine o'clock in the evening. It was not infrequent that as soon as he entered his flat conference would immediately commence with the people from the editorial board of the *Doklady Akademii Nauk SSSR* who were already waiting for him in his flat. Though he was usually bombarded with many questions, Vavilov managed to discuss them in one or one-and-a-half hour's time with no haste at all.

When Vavilov became President of the Academy, he assumed responsibility for its vast publishing activity and gave it his complete moral and practical support. Owing to his unremitting concern, the productivity of USSR Academy of Sciences Press markedly increased: within a period of five years, the output of literature was 2.5 times greater. Vavilov also considerably influenced the activities of many other publishing houses. His ties with the publishers of technical and theoretical literature as well as with Mashgiz were especially close.

The USSR Academy of Sciences Press improved its work to a great extent. On Vavilov's advice, new series of books that very soon won universal acknowledgement began to appear. They included 'The Classics of Science', 'Literary Monuments', 'Memoirs', 'Biographies', and 'Results and Problems in Contemporary Science'.

The series 'Literary Monuments' presents no little interest as far as its history is concerned. In 1947, in connection with the expected visit to the USSR of India's Prime Minister Jawaharlal Nehru, Vavilov thought of publishing *The Journey Across the Three Seas*, which was written by Afanasii Nikitin, the famous traveller and the first Russian to go to India. The book was a great success, which inspired Vavilov to issue a whole series of books under the title 'Literary Monuments'.

A special editorial board was set up for this series with Vavilov himself keeping a vigilant eye on its work.

The series is even now being published. It already comprises more than three hundred works which cover all periods and people in every corner of the world. The books are provided with wonderful commentaries and are compiled so as 'to make the reader fully enjoy them' as Vavilov used to say. Vavilov's role in the organization of this remarkable series of books was given due credit by Academician Dmitri Likhachev in his talk at the 'Ostankino' television centre in 1986.

Vavilov believed that young scientists should acquaint themselves with the classic works of science through the original sources rather than textbooks. He used to say that the study of the work itself had tremendous educational significance and had a decisive impact on the formation of one's world outlook. He himself did all he could to familiarize the new generation with the great past of science, in particular, in Russia. 'If the literary

heritage of Horace, Shakespeare, Pushkin, and other great poets is studied in minutest detail, the remarkable classics of the natural sciences are often doomed to inequitable oblivion,' Vavilov used to say on many an occasion.

In 1948, on Vavilov's initiative, the book *Men of Russian Science* was published. It was a two-volume edition containing essays on the life and activity of Russian scientists who had left an indelible trace on the history of the natural sciences and technology. In the preface to this impression Vavilov wrote, 'The unanimous patriotic enthusiasm of our people in the years of the Great Patriotic War was accompanied by a very special kind of interest in our history. Much of what had fallen into abeyance returned to people's memory, and many glorious names came back to life.'

In the same year, Vavilov also raised the question of publishing in the Soviet Union the classical works of physicists, mathematicians, astronomers, and geophysicists of the bygone days. Vavilov laid particular stress on the importance of producing books and monographs devoted to the life and activity of the outstanding people of science, considering that the works of those who had enriched Russian science should be the first to see the light of day.

Many wonderful creations of Russian and foreign scientists were extracted out of the dust of libraries, as Vavilov used to say. Thus, in 1946 the series 'The Classics of Science' acquainted the readers with the long-forgotten works of the Russian scientist Mikhail Tsvet, the founder of adsorption chromatographic analysis, which is nowadays a commonly used method. These works did honour to Russian science.

In 1950, the same series contained the selected works of the remarkable Russian physicist and electrical engineer Emil Lents. In connection with the two hundred and fiftieth anniversary of the birth of the French physicist and founder of photometry Pierre Bouguer, which fell in the year 1948, the translation of his celebrated optical treatise on the gradation of light was published. In the field of photometry, 'Bouguer', in Vavilov's words, 'is as illustrious a figure as Kepler and Newton' are in their own fields of study.

In autumn 1945, Moscow University suffered the loss

of Professor Aleksandra Glagoleva-Arkadyeva, who in her time had proved the unity of spectrum of electromagnetic waves. Her experiments had filled the gap between the radio-frequency range and the infrared spectral region. Vavilov began to exert some effort to get her works published. He was convinced that the name of Glagoleva-Arkadyeva should stand next to that of Sofya Kovalevskaya in the history of Russian science. In 1948 her works were published.

Sergei Vavilov's love for books was genuine and he greatly appreciated the way in which printed matter was arranged. It was with great bitterness that he had written the following words: 'Regretfully we have to admit that in purely technical terms, as far as their outer form is concerned, our Soviet books, in most cases, have not yet reached an adequate standard of quality. First and foremost, we cannot possibly remain heedless of the fact that there is a certain lack of consistency in the format of our books... Many of them are printed carelessly and their general appearance leaves much to be desired.'

Vavilov said that it was high time that the Soviet books were rated among the best ones in the world not only by their content, but also by the way they are designed. He compiled special instructions as to how the series of books issued by USSR Academy of Sciences Press were to be arranged. In these instructions he wrote that 'outwardly, all the publications should be strictly in conformity with a particular pattern, and that no deviations from the accepted standard could be allowed'. His translation of Newton's *Lectures on Optics*, which came out in the series 'The Classics of Science', became a model according to which the forthcoming editions of this type were prepared. Special attention was paid to thorough editing and final checking of the text.

Vavilov became very much displeased when there was a list of errata at the end of a book. In such cases he would say, 'Oh, what a shame!' Sometimes he designed the covers of his books himself. For all the acedemic editions he prepared a single imprint which represented a circle containing a drawing of the building of the Chamber of Curiosities in Leningrad. Vavilov never failed to give due credit to the well-organized sale of books and the proper management of libraries. He also did much work to initiate the microfilming of books.

N. Smirnova recalled that every Sunday morning one could see Vavilov rummaging through the books in the bookshop of the USSR Academy of Sciences 'Akademkniga' in Gorky Street. Once a week, as was his custom, he would finish his work in the Presidium a bit earlier and would go to the book section of the Academy. On these days there was nothing that could detain him. Copies of newly published books that came out under the auspices of the Academy were regularly sent to Vavilov for his inspection. N. Smirnova used to put these copies on his desk and Vavilov would look through them before beginning to work.

Professor Vladimir Semenchenko told the author of this book that he had once met Vavilov, not long before his death, at the Moscow House of Scientists, where on the first floor the Academy's book section was situated. A huge pile of books w was waiting to be looked through by Vavilov. Semenchenko jokingly said that he envied him. Vavilov smiled sadly and replied that for want of time he was very often obliged to be contented with a mere glance at their titles. This was undoubtedly an exaggeration. Everyone was always amazed by Vavilov's extensive knowledge of fiction and the latest scientific literature. He must have done his reading at night. Semenchenko himself was surprised by how Vavilov could possibly manage to be *au courant* with so multifarious a scope of problems.

Professor Maria Savostyanova recalled that at the bookshop 'Akademkniga', which Vavilov visited each time he came to Leningrad, they treated him as if he were their own manager who had been keeping his eye on their work every day in exactly the same way as in those establishments and laboratories of which he was in charge.

In his spare time, Vavilov liked to frequent the second-hand bookshops where he was primarily interested in books on history and arts. The books he bought did not remain unread for any long period of time. By the end of his life his home library had about thirty-seven thousand volumes. He had also found a copious amount of interesting reading matter for the library of the Lebedev Physical Institute of the USSR Academy of Sciences, and for his friends and acquaintances.

Vavilov never refused to do translations and frequently contributed articles to journals. As far back as 1936, on the suggestion of Academician D. Rozhdestvensky,

he took part in the Russian translation of the fundamental work by the American physicist R. Wood *Physical Optics*. He contributed significantly to the journal *Uspekhi Fizicheskikh Nauk* (Achievements of Physical Sciences). In it he published synopses and articles, always saying that the summaries of scientific works and reviews were by no means of minor importance since they help 'to discover grains of gold in the mass of sand'. He could not tolerate works that were drab or lacking in interesting content. He said that 'all measures should be taken to save mankind from reading books that are bad and useless'.

In February 1949 Sergei Vavilov was appointed editor-in-chief of the second edition of the Great Soviet Encyclopedia. He regarded this appointment not only as an honourable, but also as a highly responsible, assignment. Vavilov deemed it necessary that each potential entry in the encyclopedia should be widely discussed by the scientific world and repeatedly confirmed before it could be printed as such. The articles were sent for reviewing to various institutions as well as to eminent scientists. Sometimes scientists from the Socialist countries were also involved in this kind of work. Vavilov repeatedly said that the elaborate and painstaking reviewing of articles for the Encyclopedia was not a favour, but the duty of every scientist.

The editing of the encyclopedia called for no little effort. Vavilov thoroughly inspected every volume from beginning to end and often repeated to his colleagues: 'I hope we don't have anything of that "forgetful hound" business here!' (this was the heading in one of the volumes of the well-known prerevolutionary multi-volume encyclopedic dictionary compiled by Brokhaus and Efron under which the reader could find a short but spiteful article against the edior-in-chief of that dictionary, who had approved its publication, together with the other volumes, without even giving it a cursory glance).

If there was an article that did not meet Vavilov's demands, he either corrected it or wrote it anew. Vavilov had acquired extensive experience in compiling this kind of material when as far back as the thirties he had taken an active part in editing the first issue of the Great Soviet Encyclopedia for which he had written about sixty entries. Vavilov also participated in the publication of

the Technical Encyclopedia, in which, under his editorship, the eighth and the ninth volumes devoted to problems in optical studies were issued.

Sergei Vavilov said that the Great Soviet Encyclopedia should be the best encyclopedia in the world. He often reminded the editors of their enormous responsibility, and impressed on them the fact that when editing an article one always had to take into consideration the reader, imagining oneself in his or her place. In his opinion there was nothing worse than the embarrassment that one was bound to experience when brought face to face with the readers when the work was unsatisfactory.

In preparing the encyclopedia there was nothing too trivial for Vavilov. He aimed at making the articles accessible to the reading public at large and yet of impeccably high quality and replete with concrete reference data. Vavilov paid particular attention to the compilation of bibliographies that were to supplement the entries. He said that even an entry containing not more than several lines but provided with bibliographical information acquired no minor importance.

Professor A. Zvorykin recalled that once Vavilov came across a short article consisting of five lines devoted to the kind of monkey-like animals known as lemurs. Vavilov insisted on the article being supplied with a bibliography. When he saw that the editors regarded his suggestion as 'superfluous', he gave the following explanation: 'To us—indifferent to lemurs—this kind of bibliographical information may seem to be redundant, but the reader who will refer to the Encyclopedia for this information is undoubtedly interested in these animals. And since you are pressed for space and cannot say much on the subject, you should certainly direct the reader to the appropriate literary sources.'

Vavilov was very particular about the choice of illustrations and saw to it that each of them corresponded exactly to the text and was executed on a high professional level.

As far as the language was concerned, Vavilov spared neither himself nor others. He had a sense of profound responsibility for every single word that was printed. He could not stand the word 'appear' in phrases like '...appears to be...' and always substituted other words for it: 'Whose appearance do you have in mind?' was his

sneering comment when he came across this word in an article, letter, an official document, or some reference. He demanded that epithets like 'most prominent', 'most outstanding' and others of the same kind should be used as rarely as possible. He used to say in jest that these attributes were only apposite in reference to the then USSR Minister of Higher Education Sergei Kaftanov, a man of prominent stature and powerful constitution.

Vavilov managed to prepare for publication only the first seven volumes of the second edition of the Great Soviet Encyclopedia, though his influence on the compilation of the glossary (comprising more than one hundred thousand words), the arrangement of the entries, the selection of illustrations, the making of the bibliography, and the whole style of the preparation of the materials for publication was so great that there is every reason to regard this encyclopedia as the product of Vavilov's own effort. Several hours before his death he was still giving instructions to those working on the encyclopedia.

Sergei Vavilov invariably felt indignant when the translation of some scientific work was undertaken by a person who was incompetent in the given branch of science, and it was not infrequent that he displayed examples of unacceptable translations. Thus, on one occasion (which I happened to witness myself) he spoke of the translation of a monograph on semiconductors which had been done by a lady who was quite at home with English novels but was a congenital ignoramus in physics. Her work contained quite a few absurdities of the type 'a stripped conductor was running about the railway carriage'. When he was telling us this story his laughter became quite infectious.

'If in the past there were only a few people such as Galileo, Lomonosov, Euler, Mechnikov, and Timiryazev who had the gift of writing in a manner that presented absorbing interest and could readily be apprehended by both the specialist in the field and the public at large, nowadays it should become a requirement for every Soviet scientist,' Vavilov would say. He regarded the popularization of scientific knowledge not as a secondary duty, but as one of the most important duties of Soviet scientists.

He himself did this kind of work with great eagerness

and remarkable mastery. As far back as the middle of the twenties he wrote several successful popular science books and articles and continued to do so all his life. His book *The Experimental Foundations of the Theory of Relativity* remains peerless in world literature. The book *The Eye and the Sun*, which was already mentioned several times, came out in ten editions in both Russian and many other languages, with each new edition that came out during Vavilov's lifetime containing new material. This book, which in 1952 was awarded the USSR State Prize, continues to enjoy popularity with its readers. Among Vavilov's other popular science books that have so far not been mentioned, *The Activity of Light*, *Solar Radiation and Life on Earth*, *The Cold Light*, *Lomonosov and Russian Science*, and *Concerning 'Warm' and 'Cold' Light* present special interest.

As head of the academic commission on the publication of popular science literature over a period of thirteen years, Vavilov did much work to attract a wide circle of scientists to popularizing literature. Under his guidance there were marked improvements in the regular publication of not only popular science books for the purpose of effectuating the exchange of information, between scientists in different fields, on the latest achievements of Soviet and world science, but also of popular science editions intended for the public at large. Vavilov considered the writing of popular science books as something highly significant and calling for creative efforts. He said, 'The writing of a popular science book does not mean that on reading two special books the scientist can produce a third one. The prerequisite for the latter is that it should contain something quite new'.

In his own popular science works Vavilov never evaded the yet unsolved problems in science. Quite the contrary, he most emphatically drew the attention of his readers to them and often pointed out the possible ways of their solution. He liked to reiterate the words of the great Soviet writer Gorky who said that one hardly could write about science 'as if it were a storehouse of ready-made articles'. Vavilov avoided any superficial description of even the most dynamic physical phenomena. He wanted the reader to ponder over what he had read, and to form an idea of the methodology that laid the foundation of the science and of the long and arduous path that the

researcher had to traverse before he could reveal the sum and substance of the phenomenon under investigation. Vavilov was also concerned with how the natural sciences, primarily physics, were taught in secondary schools. He was the one who initiated the creation of a series of popular science films that could be used at schools to explain the basic physical laws.

Vavilov's brilliant activity as a popularizer of science won him fame and esteem in his own country and elsewhere. Together with academicians Vladimir Obruchev and Aleksandr Fersman he is by right considered to be a classic of Soviet popular science literature.

Vavilov was one of the initiators of the All-Union Society for the Propagation of Political and Scientific Knowledge (which was later called 'Znanie'—the Russian word for 'knowledge'). It was on his advice that a group of statesmen, scientists, and people in the arts addressed the Soviet intelligentsia with an appeal to organize such a society. The initiative received the required support, and on June 7, 1947, at the Bolshoi Theatre in Moscow, the constituent congress of this Society was assembled. In the opening address, Sergei Vavilov said, 'Our society should be the conductor and the mediator of true advanced science between the specialists and the people.' Vavilov was elected chairman of the Society and guided its work till the end of his life.

On Vavilov's recommendation the Society united the Moscow Polytechnical Museum, the journal *Nauka i Zhizn* (Science and Life) and the Polytechnical library. Znanie virtually became a mass organization and initiated educational activities on quite an impressive scale. Republican branches of the Society were organized together with about two hundred local ones.

Over the three-and-a-half years during which Vavilov was chairman of the Society, the number of its members increased by three hundred thousand. Among them there were very prominent representatives of Soviet culture and science, production innovators, and advanced workers in agriculture. Within the same period more than two million lectures were delivered; they were attended by two hundred million people. Vavilov often and willingly gave lectures on popular science subjects himself. The lectures, containing absorbingly interesting material on the latest scientific achievements, were understan-

dable to all. The publishing activity of the Society was expanded and one hundred million copies of about two-and-a-half thousand different booklets were produced.

In 1972, newspapers carried the following item: 'The Sixth Congress of the All-Union Society 'Znanie' has completed its work at the Kremlin'... That same day flowers were laid at the monument to Karl Marx and on the grave of one of the founders of the 'Znanie' Society and the first chairman of its administrative board—the outstanding scientist S. I. Vavilov.'

With the support of the Komsomol, Vavilov organized the 'Lomonosov Readings' (which were mentioned before) for the young people in Moscow, the aim of which was to fully acquaint the youth with the multilateral activity of the great Russian scientist, to awaken in them a love for knowledge, science and technology. On the basis of his lectures delivered to the young audiences, Sergei Vavilov wrote the aforesaid book *Concerning 'Warm' and 'Cold' Light.*

Vavilov worked as the editor-in-chief of the journals *Priroda* (Nature) and *Nauka i zhizn* (Science and Life), and was a member of the editorial board of the magazine *Znanie—sila* (Knowledge is Power). All that Vavilov did to popularize science is so great that it can hardly be attributed to the efforts of just one single person.

THE MEMORY OF MANKIND

Vavilov's whole life was characterized by tireless labour. He did not allow himself respite even when he was on holiday: he regarded the time on leave, which was free from the bustle of current activities, as an opportunity to concentrate in earnest. Professor Grigori Spivak told the author of this book that in the thirties he frequently went on holiday in the Crimea, to a sparsely inhabited placed Batiliman where there were only a few cottages (datchas) for scientific workers. The Vavilovs occupied a small house very close to the sea. What could be called Vavilov's vacation consisted in that he used to find a study place in the shade where he did his reading and writing, interrupting his work but briefly. He valued his time so much that he never took part in what is usually referred to as recreational activities.

Recalling the holiday he spent with Vavilov near Moscow in 1930, his friend E. Shpolsky wrote that Vavilov's vacation was scheduled in a very particular way. Not busy with teaching, he used to spend the first three days of the week in Moscow, working very hard at home and in the laboratory. His irregular meals consisted mostly of tea and cakes, which he liked very much. At the end of the week he would come to his country house, where he would continue writing. Sometimes Shpolsky and he would go to the birch forest that was close by to look for mushrooms. Vavilov was also an expert in this field, and he used to gather them with utmost skill.

Academician B. Vvedensky said that Vavilov spoke of a ten-hour working day as of a kind of holiday schedule for a scientist, since he himself worked considerably more. According to Vvedensky, Vavilov's concept of 'rest' itself was very peculiar. Presumably it was precisely what made him once say that the academic summer-cottage communities should serve as places for creative activity rather than those of recreation alone.

The overly strenuous work could not but affect Vavilov's health. At the end of the forties his heart and lung diseases, which he had contracted during the war, evidenced signs of recrudescence; thoughts about the death of his brother Nikolai and the tragic end of Nikolai's son Oleg (Sergei's nephew) in the mountains, were becoming ever more aggravating. Vavilov took great precautions lest even his wife and friends should find out anything about his own poor state of health.

Vavilov's wife Olga used to recall that her husband's intransigent disregard of his illness had always had an onerous effect on their life. E. Shpolsky told the author of the present book that Vavilov had been alsolutely merciless to himself. Doctors had invariably complained about him, saying that he did not let them treat him.

I. Frank wrote that not long before his death Vavilov once said that within the period of the past fifteen years there had not been a day when he did not manage to do some work. In Academician I. Bardin's words, it seemed to all that Vavilov was in good health since he never complained of it to anyone. Therefore the news came quite unexpectedly that Vavilov was seriously ill. He was said to have been obliged to find even enough strength before asking anyone to come to his study.

By the summer of 1950 Vavilov's health had deteriorated to the point where he had to interrupt his work and leave for his country house in Mozzhinka. He made use of the holiday that he was compelled to have for the summing up of his scientific activities. Reviewing his own works and those of his pupils from a single standpoint, he wrote, in July and August of 1950, his famous book *The Microstructure of Light* (passim).

Within that same period Vavilov planned his further literary work and began writing reminiscences and notes on various subjects pertaining to the natural sciences and philosophy. He did this as meticulously as he did everything else. He began writing in thick and properly bound notebooks that looked more like books themselves and had been ordered by him for this special purpose. His handwriting was legible and there were practically no corrections since everything that was to be entered into the notebooks had previously been thought over in detail. These notes are very interesting and contain many original ideas, which still await the researchers who will lend their insight.

In general, over a period of four and a half years—from July 1946 till the very last day of his life—Vavilov kept a diary in which he wrote down his ideas. All in all there are one hundred and sixty-three entries of this kind, which were the result of his meditations during his walks, train journeys, etc. Most of these notes were written on Sundays and during his holidays.

Vavilov often wrote of his scientific plans. Thus, on May 11, 1947, he made a short note under the heading 'About the intended book and articles'. The text of that note is the following: '(1) an article (for the United States) on science and dialectical materialism; (2) a collection of philosophical and historical articles; (3) a new edition of *The Eye and the Sun*; (4) a new edition of *Newton*; (5) an annotated translation of Boshkovich's *Dissertation on Light*; (6) an annotated translation of Leonardo da Vinci's *On the Shift of the Water Boundary*; (7) *The Fluorescence of Solutions* (a monograph); (8) 'Leonardo da Vinci' (a biography); (9) research and articles on the nature of light; (10) a reedition of *The Experimental Foundations of the Theory of Relativity*; (11) popular science articles on optics; (12) reminiscences (about 30 sheets). All this would require at least ten years of a

quiet life . Later these plans acquired an even wider scope.

Vavilov always kept his word, even if he had given it to himself. He unswervingly accomplished what he planned. Unfortunately, his comprehensive and absorbing plans were not destined to be realized. How early we lost the man who could have done yet so much good! At times he himself must have felt his approaching end. An entry in his notes dating back to July 20, 1950 reads: '... how sad it is to depart from this life when what is most essential has remained undiscovered.'

In autumn 1950 Vavilov returned to his place of work.

Professor V. Semenchenko recalled that he had met Vavilov at that time and was struck by his sickly appearance. He advised him to take better care of himself and to avoid working so much. Vavilov replied with his customary vitality, 'It's quite alright, I can endure everything—don't you know that my origin goes back to the sons of the soil. My father walked bast-shod all the way to Moscow.' But ... his health was getting ever worse. In October, when he was at the State Optics Institute, he had a very serious heart attack, and had to remain lying on the couch in the laboratory itself. The Academy's Presidium insisted that Vavilov should immediately check in at the suburban Moscow sanatorium 'Barvikha'.

In 'Barvikha' Vavilov was visited by Professor B. Sveshnikov whom he had entrusted to work on a comprehensive article about the founder of chromatographic adsorption analysis, M. Tsvet. This paper was to be included in the book on his works, which was then in preparation. Sveshnikov, aware of Vavilov's attitude to the works of Tsvet, could not possibly think of sending off his article without first having Vavilov review it.

In the sanatorium Sergei Vavilov completed his last literary work—the editing of the translation of P. Pringsheim's monograph *Fluorescence and Phoshorescence.* As was his habit, he worked very assiduously and supplied the Russian translation of the book with copious commentaries of fundamental significance as well as with an interesting preface. When the book came out, the black frame within which Sergei Vavilov's name was printed on the title page betokened the death of its author.

In Academician M. Markov's words, Vavilov had never seemed to him an old man though he was much older than Markov himself. He was regarded as perennially young by all those who knew him. It was already after his death that people began to recall how slowly he used to climb the stairs in the last period of his life and how much heavier he found his bag to be. But his will-power would invariably overcome that weakness and he would become his former self again—always active, amiable and spruce.

On January 12, 1951, curtailing his stay at the sanatorium, Vavilov returned to Moscow to resume his regular work. But . . . his days were numbered. The last day of his life—January 24, 1951—was one of his busiest days as usual. He arrived at the Lebedev Physical Institute in the morning. It was Wednesday—the day on which the seminars were regularly held. The agenda included a report by Zinaida Morgenshtern on her research on the luminescence of diamonds (the work was done under the guidance of Vavilov). Vavilov began the meeting with a joke saying that those present would now have the opportunity to hear Zinaida Morgenshtern talk about her family jewels. His good-humoured attitude immediately created an unrestrained atmosphere.

After the meeting Vavilov went to the laboratory of Yevgeni Bukke, who was working on improving luminescent lamps for the illumination of streets, and then also dropped in at Zinaida Trapeznikova's laboratory. In the middle of the day Vavilov went to the construction site of the new building of the Physical Institute. When he returned to the Presidium he occupied himself with his daily routine, met people from the Great Soviet Encyclopedia, and amended the proofs that were brought to him. Nataliya Smirnova recalled how the corrections on the first pages were made in a legible and steady hand, but then the handwriting changed and became more blurred. Vavilov was obviously overstrained.

N. Smirnova describes the end of S. I. Vavilov's day as follows: 'I shall never forget the last evening of January 24. There were quite a few things that were keeping Sergei Ivanovich at the Presidium. The last one to visit him was Academician P. Yudin who had then returned from China. He was telling Sergei Ivanovich of his trip and the laughter that was heard from Sergei Ivanovich's

office was taken to be a sign that the conversation between them was gay and lively. When P. Yudin left, Sergei Ivanovich came out of his room, wished us good evening, and seeing I. Papanin, who was sitting beside my table, stopped and said, "Ivan Dmitrievich, the instructions of the Presidium must be carried out". (I don't remember what they were actually about.) Then he went to as far as the door, stopped again and said to us, "Tomorrow I shall be in at one o'clock as usual".. . . But that tomorrow never came.'

On returning home Vavilov went to bed immediately and fell asleep. At about midnight he didn't feel well and the doctors had to be called. Professors Vladimir Vinogradov, Miron Vovsi and Boris Egorov took all the necessary measures to make their patient feel better. Vavilov persuaded the doctors to go home and apologized for having trespassed on their time, for no good reason, as he said. In several hours' time his condition became worse again and in the early hours of the morning Sergei Vavilov passed away. He died two months before his sixtieth birthday, the date that the scientific world had been preparing to celebrate on a wide scale.

Reflecting about S. Vavilov, Academician A. Lebedev mentioned that he had been an exceptionally disciplined person, a man of honour who had always kept his word, a man of remarkable intellectual and moral qualities. He was one of those upon whom the world can safely rest. People like Vavilov leave an indelible trace after themselves: their lives serve as an example for the next generations and the memory of them is sacredly preserved in the hearts of all those who were fortunate to work with them.

On January 25 a meeting devoted to the memory of Sergei Ivanovich Vavilov took place. Speeches were given by Academicians Ivan Bardin, Aleksandr Topchiev, Vyacheslav Volgin, Ivan Petrovsky, Aleksandr Oparin, and the deputy director of the Lebedev Physical Institute of the USSR Academy of Sciences, Vadim Levshin. Everyone spoke of Sergei Vavilov's outstanding service to his country. I. Bardin said, 'He died at his post like a soldier faithful to his duty till the very last moments of his life'.

Some time later, the famous English scientist John Bernal wrote that Vavilov was a man who had been character-

ized by calm and reserved dignity. He drew great respect by the powerful reasoning, efficiency and unambiguousness typical of his personality. He died at his post presumably of exhaustion. However, what he had done for his country is far beyond what is usually assigned to a single person. Together with Lomonosov he will be regarded as one of the great founders of science in the USSR.

Sergei Vavilov's death was a grievous loss to the Soviet people and to all progressive mankind. For two days, on January 26 and 27, disregarding the extremely cold weather, thousands and thousands of people went to the Hall of Columns of the House of Unions, where the deceased was lying in state. Representatives from all over the country came to Moscow to pay their last respects to the great scientist. The Presidium of the USSR Academy of Sciences received thousands of telegrams from different countries with condolences on the irretrievable loss that Soviet science had suffered.

John Bernal sent a telegram stating that Sergei Vavilov had become a symbol of not only the purposefulness of science, but also of the true way in which science should serve the people. He wrote further that the memory of this great man and scientist was highly honoured by everyone. The celebrated French physicist Frederick Joliot-Curie sent a telegram in which he wrote that he shared the grief of the Soviet people on the death of the great scientist and his friend Sergei Vavilov, which was mourned by the whole world.

On January 27, 1951, all of Moscow attended Vavilov's funeral.

Sergei Vavilov was buried in the centre of the old territory of the New Convent of the Virgin or Novodevichy Monastyr—the resting place of outstanding people of science and culture—beside his teachers Pyotr Lebedev and Pyotr Lazarev, and close to the graves of Nikolai Zelinsky, Otto Shmidt, Aleksei Shchusev, Vladimir Obruchev, Vladimir Komarov, and Vladimir Mayakovsky. A simple monument of gray granite was placed on Vavilov's grave.

Several institutions were named after Sergei Vavilov: the Institute of Physical Probles of the USSR Academy of Sciences and the State Optics Institute, as well as the luminescence laboratory of the Lebedev Physical Institute of the USSR Academy of Sciences, which had been

created by him and of which he had been in charge for many years.

The Vavilov gold medal was issued by the Academy of Sciences. It was to commemorate outstanding achievements in physical research. Some of those who have been honoured to receive this award at different times include Dmitri Skobeltsin, Aleksandr Terenin, Ivan Obreimov, Eduard Shpolsky, Valentin Fabrikant, Boris Stepanov, Pyotr Feofilov, Vladimir Linnik, Mikhail Galanin, Ilya Frank, Sergei Vonsovsky, and Vsevolod Antonov-Romanovsky. Four grants in memory of S. Vavilov were also founded for the postrgaduate students of the physical Institute of the USSR Academy of Sciences and the Physics Faculties of Moscow and Leningrad Universities.

In December 1969, on the recommendation of the All-Union Society 'Znanie', a desk-medal bearing the name of S. Vavilov—the first Chairman of the Administrative Board of that Society—was issued. Its obverse side has a portrait bas-relief, while the words 'For the outstanding contribution to the propagation of scientific knowledge' are written on the reverse side. About twenty of the best lecturers of the 'Znanie' Society as well as foreign popularizers of science are awarded this medal every year. Since the day it was issued, more than four hundred people have had the honour of receiving it. They include: the writer Mikhail Sholokhov; Academician Anatoli Logunov, Rector of Moscow University; Karl Rebane, President of the Estonian SSR Academy of Sciences, and Academician Bogumil Kvasil, Vice-President of the Czechoslovakian Academy of Sciences. Many other well-known scientists and representatives of culture have also received this medal.

Monuments to S. Vavilov are located near the Lebedev Physical Institute of the USSR Academy of Sciences in Moscow, the State Optics Institute in Leningrad and the Byelorrusian Optical and Mechanical Centre in Minsk, and plaques commemorating those places where Vavilov worked for many years have now been placed on the buildings of the State Optics Institute and the Lebedev Physical Institute in Miusskaya Street. There is also one on the wall of the house in Ioshkar-Ola, where Vavilov lived during the war.

One of the main roads of the Oktyabrsky district in Moscow, which is bordered by the territory of the new

building of the Lebedev Physical Institute, has been named after Vavilov. There are streets bearing Sergei Vavilov's name in Ioshkar-Ola, Perm, Bukhara, and in the town of the physicists Dubna. One of the streets in Leningrad is also named after the Vavilov brothers.

In 1965, when the Soviet interplanetary probe 'Zone-3' photographed the far side of the Moon, one of its craters was given the name of 'Vavilov Brothers'. Several seavessels are also named after Sergei Vavilov, one of which is specially intended for oceanic studies. In 1961, on Sergei Ivanovich Vavilov's seventieth birthday, the USSR Ministry of Communications issued a postage stamp, a postcard and a postal envelope bearing his image.

The USSR Academy of Sciences undertook the publication of S. Vavilov's works. The commission that was organized included a large number of prominent scientists, such as: Academicians A. Topchiev, A. Terenin, G. Landsberg; Corresponding-Members of the USSR Academy of Sciences B. Vul and T. Kravets; and Professors V. Levshin, P. Feofilov, M. Galanin, J. Kuznetsov, and V. Vavilov. Its chairman was Academician A. Lebedev. In 1956 the edition was completed.

This collection of works, consisting of four volumes, contains papers on various topics in science. The list of the scientist's published materials comprises over three hundred items.

In February 1976, on the eve of Sergei Vavilov's 85th birthday, the Lebedev Physical Institute of the USSR Academy of Sciences organized the First All-Union Vavilov Readings on luminescence. Since then they have become a tradition. Every year those who have read reports at these sessions are given memorial diplomas commemorating their participation in the event that is an honour for every physicist.

In 1981, the USSR Academy of Sciences, and with it the whole of the Soviet Union, commemorated the ninetieth anniversary of Sergei Vavilov's birth. This event was marked by a special session of the Academy, which was held under the chairmanship of its president Anatoli Aleksandrov at the Moscow House of Scientists, as well as by the All-Union conference on luminescence in Leningrad.

Many years have passed. It has already been more than

thirty years since Sergei Vavilov left the ranks of Soviet scientists. When thinking of him one cannot but bring back to mind the words once said by Abraham Lincoln, the former president of the United States, that a big tree can be measured only when it is felled. And indeed it is only now that one begins to fully comprehend how great Vavilov's contribution to his country's science was. We think of it each time we find ourselves in some research institute or higher educational institution, or when we see his picture among those of the world's outstanding scientists.

Time is inexorable. Less and less of those who were under his immediate guidance remain with us. Those who hold the foremost positions in science are his scientific grand- and great-grand children, which proves how right he was in laying so much emphasis on the continuity in science. If, in the days when Vavilov and Levshin were young, they were practically the only two to start conducting research on the luminescence of liquids, and A. Terenin was the only one to do this kind of work with gases, there are nowadays hundreds of Soviet scientists who are conducting research on the cold glow of substances. Huge scientific centres have emerged in the country which focus mainly on the study of luminescence and its practical application.

Sergei Ivanovich Vavilov has forever entered the memory of mankind as a person whose talent, devotion to his work, patriotism and sublime spirit have made him virtually immortal.

Major Dates of S.I. Vavilov's Life and Activity

1891 **12 (24) March**	Sergei Ivanovich Vavilov was born in Moscow.
1901-1909	Pupil of the Moscow Commercial School.
1909-1914	Student of the Physics and Mathematics Faculty of Moscow University.
1911-1914	Scientific work in the physics laboratory under P. Lebedev and P. Lazarev.
1913	The first scientific article 'The photometry of sources of different colours'.
1914-1918	At the Front. Two original investigations in the field of radio engineering.
1915	Received a gold medal from the Society of Amateurs in the Natural Sciences, Antropology and Ethnography at Moscow University for the research report 'The thermal decolorization of dyes'.
1918-1930	In charge of the department of physical optics at the Physics and Biophysics Institute of the RSFSR Commissariat for Public Health.
1918-1929	Assistant Professor in the Physics and Mathematics Faculty of Moscow University.
1918-1927	Lecturer and then professor at the Moscow Higher Technical School.
1919	Received the Master's degree in Physics at Moscow University.
1919-1920	The first investigations on the experimental verification of the quantum properties of light.
1920	Sergei Ivanovich Vavilov married Olga Mikhailovna Bagrinovsky.
1920-1929	Professor of physics at Moscow Higher Zootechnical Institute.
1922	Publication of the first popular science book *The Activity of Light*.
1923	Fundamental research on polarization properties of the luminescence of dye solutions (in collaboration with V. Levshin). Derived the formula explaining the degree of polarization of luminescence during the excita-

	tion of the glow by linearly polarized and ordinary light (the Vavilov-Levshin formula).
1924	Developed the method for experimentally determining the absolute values of the efficiency of the luminescence of solutions (Vavilov's method).
1926	A scientific mission to Germany.
	The determination of the relationship between the processes of fluorescence and phosphorescence in liquids and solids (in collaboration with V. Levshin).
	The discovery of the first nonlinear optical effect—a deviation from Bouguer's law with uranium glass (in collaboration with V. Levshin).
1927	Determined the dependence of the efficiency of the luminescence of dye solutions on the wavelength of the exciting light (Vavilov's law).
	Translated Newton's *Optics* from the Latin.
	The publication of the popular science book *The Eye and the Sun.*
1928	The publication of the popular science book *The Experimental Foundations of the Theory of Relativity.*
1929-1932	Professor and Head of the Department of General Physics at the Physics and Mathematics Faculty of Moscow University.
1929-1932	Full Member of the Physics Research Institute at Moscow University.
1930-1932	Chairman of the production committee of the physics section of Moscow University.
1931	Elected Corresponding Member of the USSR Academy of Sciences.
1932	Elected Full Member of the USSR Academy of Sciences, and appointed deputy director responsible for scientific research at the State Optics Institute.
1932-1941	Completed a series of classical works at the State Optics Institute on the quantum fluctuations of light.
1932-1951	Director of the Lebedev Physical Institute of the USSR Academy of Sciences.
1933	The discovery of a new type of optical glow (in collaboration with P. Cherenkov)—Vavilov-Cherenkov radiation.
1933-1951	Chairman of a commission of the USSR Academy of Sciences concerned with the publication of popular science literature.
1933-1945	Member of the editorial board of the journal *Doklady Akademii Nauk SSSR.*
1934-1938	Chairman of a commission of the USSR Academy of Sciences that conducted studies on the stratosphere.

1934-1951	Head of the luminescence laboratory at the Lebedev Physical Institute of the USSR Academy of Sciences.
1934-1936	Head of the physics and mathematics section at the Institute of the History of Science and Technology of the USSR Academy of Sciences.
1935	Elected member of the Leningrad Soviet People's deputies.
	A mission abroad with the aim of becoming acquainted with the research of optical laboratories and factories.
1938-1951	Chairman of the USSR Academy of Sciences commission on the atomic nucleus.
1938	Elected member of the Presidium of the USSR Academy of Sciences.
1938-1947	Deputy of the RSFSR Supreme Soviet.
1938-1951	Chairman of the USSR Academy of Sciences commission responsible for studies in the Academy's history.
1939	Awarded the Order of the Red Banner of Labour.
	Elected deputy academician-secretary and member of the bureau of the physics and mathematics department of the USSR Academy of Sciences.
1939-1951	Managing Editor of the *Journal of Experimental and Theoretical Physics*.
	Managing Editor of the *Journal of Physics, USSR*.
	Chairman of the editorial board of the journal *Priroda* (Nature).
1941	Directed creation of the first experimental samples of luminescent lamps.
1943	Appointed representative of the State Committee for Defence.
1943	Awarded the Order of Lenin.
	Received the USSR State Prize of the 2nd Class for the research reports on physical optics entitled 'The theory of concentration depolarization of fluorescence in solutions' and 'The visual measurements of quantum fluctuations'.
	Received an honorary diploma of the Presidium of the Supreme Soviet of the Mari ASSR.
	Publication of the popular science book *Isaac Newton*.
1943-1951	Deputy Chairman of the Physiological Optics Commission of the USSR Academy of Sciences.
1944-1946	Chairman of the USSR Academy of Sciences commission responsible for scientific and technical supplies.
1945	Received the Order of Lenin.

	Received the Medal 'For Valiant Labour in the Great Patriotic War of 1941-1945'.
1945-1951	President of the USSR Academy of Sciences. Chairman of the USSR Academy of Sciences commissions on studies of luminescence and the history of the physical and mathematical sciences. Chairman of the editorial and publishing board of the USSR Academy of Sciences. Editor-in-chief of the journal *Doklady Akademii Nauk SSSR*. Editor-in-chief of the USSR Academy of Sciences periodical *Information on the Bibliographies of the Scientists of the USSR*.
1946	Received the State Prize of the 1st Class for the discovery of a new type of glow (in collaboration with I. Tamm, I. Frank, and P. Cherenkov). Elected deputy of the Supreme Soviet of the USSR by the Lenin district constituency of Moscow. Publication of the translation of Newton's *Lectures on Optics*. Elected honorary member of the Academy of Sciences of Kazakh SSR and the Moscow Society of Naturalists.
1946-1951	Chairman of the USSR Academy of Sciences Council for the Coordination of the Activities of the Academies of Sciences of the Union Republics. Chairman of the Scientific and Technical Society of Instrument Engineering.
1947	Elected deputy of the Moscow City Soviet of Working People's Deputies. Also elected honorary member of the Uzbek and Bulgarian Academies of Sciences, and the Committee for Scientific Research of the Mongol People's Republic. Elected Corresponding Member of the Slovenian Academy of Sciences and Arts (Lyublyana, Yugoslavia).
1947-1951	Chairman of the All-Union Society for the Propagation of Political and Scientific Knowledge. Editor-in-chief of the journal *Priborostroenie* (Instrument Engineering).
1948	Received the Medal 'In commemoration of the 800th anniversary of Moscow'. Elected honorary member of the Academy of Sciences of Armenian SSR and honorary doctor of the Prague University.
1949	Appointed Chairman of the Physics Section of the Committee for the Conferring of the USSR State Prizes.

	Publication of the popular science book *Concerning 'Warm' and 'Cold' Light.*
	Elected corresponding member of the Academy of Sciences of India.
1949-1951	Editor-in-chief of the second edition of the Great Soviet Encyclopedia.
1950-1951	Publication of the monograph *The Microstructure of Light.*
	Elected member of the Presidium of the Soviet Peace Committee.
	Elected deputy of the Supreme Soviet of the USSR (Lenin District Constituency of Moscow).
	In the same year elected honorary member of the Polish Academy of Sciences and corresponding member of the GDR Academy of Sciences in Berlin.
1951	On January 25 Sergei Ivanovich Vavilov died in Moscow.
	The USSR State Prize (2nd Class) was awarded (posthumously) for the elaboration of luminescent lamps (in collaboration with V. Levshin, M. Konstantinova-Shlezinger, V. Fabrikant, F. Butaeva, and V. Dolgopolov).
1952	The USSR State Prize of the 1st Class awarded (posthumously) for the outstanding scientific research in the field of physical sciences and for the publications *The Microstructure of Light* and *The Eye and the Sun.*
1967	S. Vavilov's name was entered into the Book of Honour of the All-Union Society 'Znanie'.

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